"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal Fluid)"

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Date : 12 JUNE 2006

ANALYSIS OF BIOMASS GASIFIES TO PRODUCE FUEL GAS USING PALM OIL WASTE IN MALAYSIA

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A project submitted in partial
fulfillment of the requirement for the award of
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May 2006

"I hereby declared that this thesis is my own work except the ideas and summaries which I have clarified their sources"

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Date : 12 JUNE 2006

"In name of ALLAH"

Specially dedicated to person who believes in me, especially to my father and mother (Allahyarham Baharudin & Allahyarham Norkamariah), Noorhafizah Che'Su my lecturers and my friends.

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"In the name of ALLAH, the most Gracious and most Merciful"

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ABSTRACT

This study address issues on biomass production for energy using gasification process pyrolysis. In Malaysia, energy produced from the source of biomass still at the lower contribution for the total of energy used. To enhance the usefulness of the energy from the biomass, we have design a furnace, storage systems and also the distribution system for supply the energy or fuel gas from biomass to the rural communities in remote electrified village. By using a pyrolysis process, gasification process and also combustion process, we have found a new way of producing cooking gas using agricultural waste (palm oil). The land use, energy used pattern and energy demand in Malaysia were the first things that would to know. The reason is to make an analysis for the number of the power produced and how much area need to be supplied of the cooking gas with a specific value of power or volume of gas.

ABSTRAK

Pengajian kajian ini adalah mengenai penghasilan biojisim untuk tenaga dengan menggunakan proses pyrolisis. Di Malaysis, tenaga yang dihasilkan melalui kaedah biojisim adalah masih berada di tahap yang sangat rendah berbanding dengan jumlah tenaga yang ada di Malaysia. Bagi meningkatkan penggunaan tenaga melalui kaedah biojisism ini, kami telah mereka-cipta alat pembakaran, sistem penyimpanan gas, dan juga mereka-cipta system agihan bagi menyalurkan gas ini kepada komuniti luar bandar yang tidak mempunyai kemudahan tenaga elektrik. Dengan menggunakan kaedah proses pyrolisis, pengewapan dan pembakaran, kami telah menemui satu kaedah baru bagi penghasilan gas memasak dengan menggunakan hasil buangan sisa pertanian iaitu sisa pejal kepala sawit. Bentuk penggunaan tanah, penggunaan tenaga dan juga permintaan penggunaan tenaga di Malaysia merupakan satu langkah yang pertama yang perlu di kaji. Alasannya ialah bagi melakukan analisis jumlah kuasa yang dihasilkan dan berapakah keluasan komuniti yang diperlukan bagi membekalkan bekalan gas memasak dengan jumlah kuasa atau isipadu gas yang tertentu.

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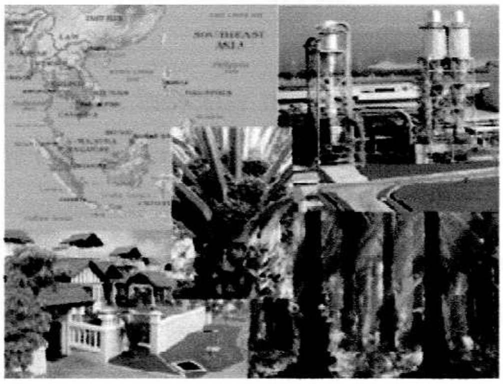
CHAPTER 1

INTRODUCTION

This chapter discussed about the overview of the biomass process involved in Malaysia. Before that, the description about land used for palm plantation, population of people in Malaysia and energy used pattern either energy from the petroleum, electricity or renewable energy. Biomass demand also discussed but not too specific and detail because the number of biomass demand is quite smaller rather than demand for petroleum energy.



1.1 Overview

Biomass energy has attracted steadily increasing attention as a promising renewable energy to cope with global warming and the depletion of fossil fuel resources. There are many types of technologies for converting biomass to electricity or to a secondary fuel such as methanol or biomass oil. Direct combustion, gasification, and reforming biomass-derived hydrocarbon are the technologies for electricity generation. Biomass oil produced by liquefaction or pyrolysis can be used for heat demand. Biomass gasification is also used to generate syngas which can produce methanol. Methanol can then utilized various purposes such as electricity or heat generation and a source of hydrogen. Hydrogen by biomass reforming can be used for on-board automotive fuel cells as well as on-site fuel cells for factories, hotels, or other businesses. Biomass gasification has two promising processes, that is, conventional thermal gasification and novel supercritical water gasification. Since a large variety of processes and uses are possible for biomass energy, the energy efficiency should be evaluated via the life-cycle approach from the acquisition to the final utilization. On the other hand, it can be pointed out that the comparison of energy efficiency is not very significant since CO2 reduction by improving the efficiency of energy conversion is much smaller than that of by substituting fossil fuel to biomass, which is regarded as a CO2 neutral fuel. However, even if biomass is renewable energy in the long term, the amount of utilizable energy in the world is limited in a short term. Energy efficiency is also important from the viewpoint of cost. It is, therefore, important to utilize the biomass energy efficiently in the future when biomass energy substitutes fossil fuel.

The world energy demands are basically met by fossil fuels such as oil, coal and natural gas. The foreseeable depletion of these fossil fuel reserves within the next 40–50 year and the expected environmental damages due the global warming have catalyzed the world to shift towards renewable energy sources which are less environmentally harmful. According to the world energy council projections, if the adequate policy initiatives are provided, in 2025, 30% of the direct fuel use and 60% of global electricity supplies would be met by renewable energy sources. Bio-energy basically comprises of energy from fuel wood, wood residues, agricultural residues, animal wastes, and etc. If these bio-energy supplies are maintained in a sustainable way, they can contribute positively to the local and global environment. Biomass grown in deforested land and degraded areas help to restore the biodiversity of the system and also to prevent soil erosion. Biomass supply particularly fuel wood involves a whole range of economic activities: from growing to harvesting to processing to wholesaling to transporting and to retailing the product. Renewable energy sources like solar and wind have limitations due to the form of energy they produce. Bio-energy on the other hand is versatile. It can be produced in gaseous form (producer gas and biogas), liquid form (alcohol), and solid form (charcoal and briquettes) adding value to commercialization. Biomass energy systems are also not site specific; these can be established in any place where plants are grown and animal wastes are available. Of these renewable, biomass has an added advantage of being able to be set up on a small scale to provide power and electricity to villages and small agglomerates or on a large scale for electrical power generation to be fed to the national grid.

1.2 Objectives of the project

Study and analyze a biomass gasifies using agricultural waste (palm oil waste) to produce fuel gas in Malaysia by focusing on the process. The process that we used is known as pyrolysis process. Besides, we also concentrate on the facilities that we need to use along the process such as furnace and reactor.

1.3 Scopes of the project

The scopes of project are as follows:

1) Study on population, energy used pattern and energy demand in Malaysia
2) Study on the biomass process by using palm oil waste
3) Study of biomass combustion process.
4) Study of gasification process pyrolysis.
5) Study about furnace that are used for combustion process.

1.4 Population

Malaysia has a population of 17.7 million in 1990 and this has increased to 25.7 million in 1997. In 2010 the population is expected to grow to 34.1 million at an estimated growth rate of 2% per year. The basic statistics of the country is illustrated in Table 1.

Table 1
Basic statistics of the country

Items	1980	1990	1997[a]	2010[b]	2020[b]
Population ('000)	13,764	17,756	25,763	34,056	42,149
Per capita GNP (US $)	983	1625	3184	5097	7545
Per capita energy use					
Commercial (kgoe)	—	670	1088	na	na
Traditional (kgoe)	25	75	120	na	na
Level of electrification (%)	65	79	85	95	na
Total oil import					
a. ktoe (total crude and petrol products)		8275	13,320	na	na
b. % consumption		42	35	na	na

[a] KTKM [3].
[b] Both population and per capita GNP growth are estimated to be the same as base year 1997 at 21.7% and 7.7%, respectively, per year.

Table 1 : Basic statistic of the country (Malaysia)

1.4.1 Current land use

The current land use pattern is shown in Table 2. A large portion of the land is allocated to natural forest where the government has committed at least 60% of the total land area of the country under forest cover. A significant percentage of the land has also been allocated to oil palm and rubber plantations. A sizable amount of land categorized as Beach Ridges Interspersed with Swales (BRIS) land, tin tailings (or ex-mining land) and idle agricultural land at 0.162, 0.114 and 0:7 Mha, respectively, has potential to be exploited for biomass production.

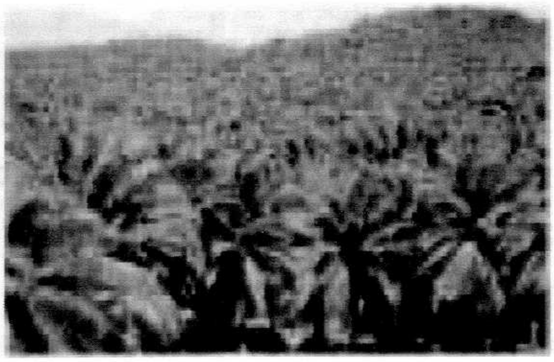


Figure 1 : Picture of palm oil plantation in Malaysia

Table 2
Land use pattern

Land use category (Mha)	1980	1990	1997[a]	2010 Projected
Natural forest	20.540	20.669	20.570	19.340
Plantation forest	0.018	0.081	0.100	0.100
Arable land and permanent pasture	1.857	1.976	2.101	2.494
Rubber plantation	2.003	1.837	1.672	1.277[b]
Oil palm plantation	1.023	2.029	2.819	3.798[b]
Others	7.256	5.399	4.729	5.122
BRIS land[c]	—	0.162	0.162	0.162
Tin tailings[d]	—	0.114	0.114	0.114
Idle land[e]	—	0.700	0.700	0.560
Total	32.967	32.967	32.967	32.967

[a] Statistics on Commodities [2].
[b] PORLA [1].
[c] H.M.S. Amir et al. [4].
[d] L.H. Ang and K.H. Lim [5].
[e] Berita Harian [6].

Table 2 : Current land used pattern in Malaysia

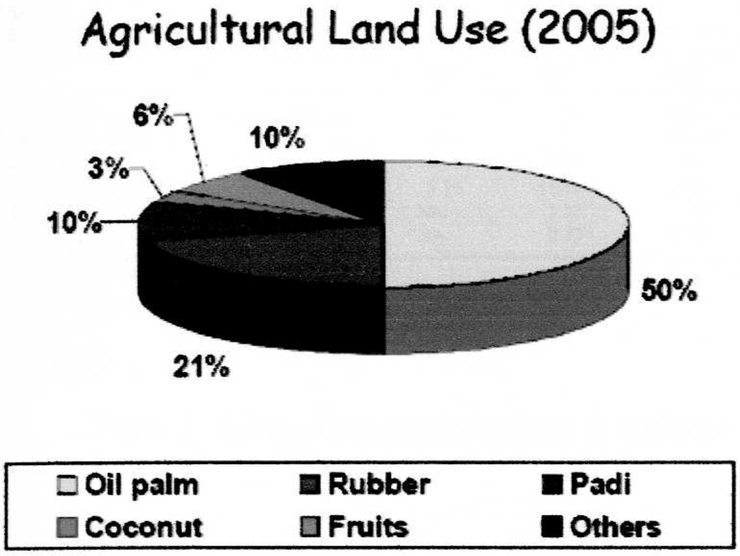


Chart 1 : Agricultural land use in Malaysia (2005)

1.4.2 Energy use pattern

The dominant source of energy in the country is still based on fossil fuel where an estimated 93% of the energy is derived in the form of petroleum and electricity produced. At present, fuel wood (traded on a commercial scale) only accounted for 0.3% of the national energy balance sheet. However, if non-commercial energy source is taken into consideration, the net contribution of fuel wood is expected to be between 10% and 15% of the total energy produced by the country. Table 3 shows the energy consumption pattern and forecast in the country.

Table 3
Energy consumption pattern in Malaysia

	1990	1997	1998[a]	Forecast 2010[b]	Forecast 2020[b]
Petroleum (petroleum product)[c] (Mtoe)	9.90	18.58	17.49	44.00	66.00
Electricity[d] (Mtoe)	1.48	3.76	4.06	9.36	21.47
Coal[c] (Mtoe)	0.51	0.74	0.77	NA	NA
Natural gas[b] (Mtoe)	5.10	11.10	13.70	21.00	35.20
Fuel wood[e] (Mtoe)	NA	2.23	2.30	2.95	NA
Crop residue[e] (Mtoe)	NA	0.77	0.79	1.18	NA

[a]Estimated figures.
[b]APO [10].
[c]NEB [7].
[d]TNB [8].
[e]RWEDP [9].

Table 3 : Energy consumption pattern in Malaysia

1.4.3 Biomass demand

In general, the demand of biomass classified under fuel wood, industrial wood and sawn wood is summarized in Table 4. The demand pattern for biomass is expected to increase steadily up to the year 2010. The major portion of this demand will come from the existing natural forest and planned plantations. However, the government has plans to maintain or increase the contribution of renewable energy following the introduction of the Five Energy Policy where renewable energy is expected to feature prominently in the country. This will mean that biomass sources will play an important role in the national energy balance.

Table 4
Biomass demand by year

Biomass demand (Mt)	1990	1997	2010
Industrial wood	18.83	19.72	21.17
Sawn wood	3.88	3.11	3.32
Fuelwood	6.32	6.87	8.34
Total	29.03	29.70	32.83

Source: FAO [11].

Table 4 : Biomass demand by year

1.5 Palm oil waste

In the palm oil mill, palm oil fruits are considered as the source to obtain the oil. In general, the normal fresh fruits bunch can be a combination:

1. Palm oil fruits 51%
2. Palm kernel 7%
3. Fibre 14%
4. Shell 7%
5. Empty fruit bunch 21%

Plantation Malaysia Performance	2004	2003	% Change
Crop - FFB (tonnes)			
- *Own*	1,428,825	1,434211	(0.4)
- *Outside*	460,760	343,297	34.2
Yield per mature hectare (tonnes FFB)	*17.7*	*19.6*	*(9.7)*
Mill production (tonnes)			
- *Palm oil*	380,929	348,210	9.4
- *Palm kernel*	105,317	100,561	4.7
Extracton rates (%)			

Table 5 : Performance of palm oil plantation

A total of about 665 MW capacity can be expected of the estimated overall potential of about 20.8 million tones of biomass residues from these main source. It is envisaged that 700 MW or 5% share of total electricity demand of the country (Malaysia) by 2005 offered to renewable energy is not difficult to achieve if the palm oil industry take up the challenge.

Region	Oil mills		Crushing factories	
	No	Capacity(Ton FB/Year)	No	Capacity(Ton Kernal/Year)
Penisular M'sia	244	4537370	30	3254600
Sabah	89	18750600	8	1057500
Sarawak	19	3620400		-
Malaysia	352	67744720	38	4312100

Table 6 : Number of oil mill and palm kernel crushing factories in operation in 2001 in Malaysia.

1.6 Chemical analysis of palm oil waste

In the chemical analysis mole balance is used, including six equations related to carbon, hydrogen, sulfur, chlorine, oxygen and nitrogen. Besides these six equations, there are six other equation's related to chemical equilibrium reactions which are given as:

CO	+	½ (O2)	=	CO2			(1)
H2	+	½ (O2)	=	H2O			(2)
SO2	+	½ (O2)	=	SO3			(3)
N2	+	O2	=	2NO			(4)
NO	+	½ (02)	=	NO2			(5)
2HCL	+	½ (O2)	=	H2O	+	CL2	(6)

The equalities mean that the reactions are reversible and from reaction (1) to (6) we used the constant of chemical equilibrium K according to equation (7). The constant Ai, Bi, Ci, Di, Ei depend on the chemical equilibrium reaction and given by table below.

$$\mathrm{Log}\,(Ki) = Ai / T + Bi\,\mathrm{Log}\,(T) + CiT + DiT^{-2} + Ei \qquad (7)$$

i	Ai	Bi	Ci (Exp5)	Di (Exp -3)	Ei	Total
1						
2						
3						
4						
5						
6						

Table 7 : Constant Used in equation (7)

1.7 Mathematical Analysis

In the combustion of palm oil waste three essential elements are formea, carbon, hydrogen and sulfur: therefore the product of combustion are related to these elements and also depend on the temperature and excess air used.

The equations are all set to zero and are represented by:

$$Fi\ (X1, X2, \ldots\ldots, X6) = 0 \qquad (\text{for } I = 1,2,\ldots..6)$$

Where Xi mole fraction of the compound I in the product writing the system as F (x) = 0 where F = (F1, F2,.....F6) (Exp t) and X = (X1, X2, ...X6) (Exp t)
Let ▲Xi = Xi Exp (j + 1) – Xi (Exp j) (j is the iteration number)

Then expand equation (8) into Taylor series and neglecting the second order and higher derivatives, therefore equation (9) is obtained.

$$Fi + (\omega Fi / \omega X1)\ \blacktriangle X1 + (\omega Fi / \omega X2)\ \blacktriangle X2 + \ldots\ldots\ldots\ldots = 0 \quad (i=1,2\ldots6)$$

Equation (9) which is obtained is called Newton'2 Method for system of non-linear equations.