BIOMASS ENERGY POTENTIAL IN MALAYSIA

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ABSTRACT

The biomass energy potential in Malaysia is assessed in relation to the availability of the varied agricultural, forestry and livestock residues in the country. Numerous biomass resources are identified for energy generation and applications. The paper will review the present management and utilization of these biomass resources for biomass energy generation and rationalise its contribution to the national energy scenario.

POTENTIAL BIOMASS ENERGY RESOURCES

The last decade has been characterized by an increased global awareness with respect to energy derived from biological processes or biomass – primarily energy uses of plant materials, animal, agro-industrial and municipal wastes. Biomass represents a renewable domestic source of gaseous, liquid and solid fuels that can be used in relatively small decentralized energy systems. With biomass currently contributing about 15% of the world's energy, equivalent to about 20 million barrels of oil per day, it is only appropriate that the short term contributions of biomass to the national energy needs be recognised.

Malaysia's economy is agriculturally based which supports a much larger population than any other form of economic activity. It is the world's premier exporter of rubber, palm oil and tropical hardwoods and, as in most developing countries, its industrialization is underlaid by the production and processing of agricultural raw materials.

During the primary and secondary processing of the agricultural commodities, a substantial amount of agro-industrial wastes is generated. The post-harvest wastage including livestock and forestry residues are potential biomass resources for energy conversion and production. The potential exists for a constant rate of production the year round; therefore energy-recovery systems could operate continuously utilizing biomass in an almost identical form at all times. Table 1 gives the potential annual availability of these biomass resources.

TABLE 1
POTENTIAL ANNUAL AVAILABILITY OF BIOMASS/RESIDUES

Biosystem	Biomass/Residues	Tonnes
1. Oil palm	Crude palm oil	4.544×10^6
	Shell	1.3×10^6
	Fibre	3.0×10^6
	Empty fruit bunches	5.0×10^6
	Effluent (5% solids)	11.3×10^6
	Trunk	74 t/ha
	Fronds	14 t/ha
2. Padi	Straw	3.1×10^6
	Husk	380,000
3. Coconut palm	Coir	207,300
	Shell	103,700
	Copra cake	40,000
	Coconut water	173,000
4. Cocoa	Pod husk (dry)	52,000
5. Tapioca	Pulp (dry)	38,000
	Starch	22,000
6. Sugar cane	Bagasse	220,000
	Molasses	60,000
	Leaves/Tops	740,000
7. Pineapple	Wastes	75,000
8. Sago	Wastes	50,000
	Starch	30,000
9. Maize	Stalk	12,800
	Cob	2,130
10. Groundnut	Shell	3,500
11. Forest	Sawn timber wastes	15×10^6
12. Rubber tree	Wood	$7-9 \times 10^6$
13. Animal (mainly buffalo, cattle, pigs)	Dung	2.76×10^6

ENERGY SCENARIO

Malaysia is highly dependent on oil in meeting its energy requirements. Although Malaysia is currently a net exporter of oil, it is imperative that due to limited oil reserves, estimated at 3.0 billion barrels, there is need to develop viable alternative energy sources. Efforts will continue to be made to pursue alternative diversification objectives by further reducing reliance on oil while increasing the role of natural gas, hydropower and coal. In ensuring that the development of energy diversification programmes is consistent with the phased development of energy supplies, an optimum energy mix will be formulated with continued focus on the utilization of domestic resources. Energy resources utilization options in the short term will include natural gas, domestic and imported coal and hydropower. In the medium to long term, the options are extended to include non-conventional energy.

Non-conventional alternative energy resources did not contribute significantly towards overall energy development due to economic and technical reasons. The contribution of biomass which includes fuelwood and palm oil mill wastes is projected to remain at about 15% even up to 1990 (Table 2).¹

Research and development activities on non-conventional energy production and conversion will be continued, particularly in the agricultural sector, to make effective use of post-harvest wastage. The potential in cogeneration system will be studied, particularly in isolated biomass power plants, with a view to increasing the overall efficiency in energy use.

TABLE 2
PRIMARY SUPPLY OF ENERGY

Source	1985 (PJ)	%	1990 (PJ)	%
Crude oil	360.2	(53.0)	360.2	(41.7)
Petroleum products	60.7	(8.9)	102.0	(11.8)
Natural gas	122.8	(18.1)	179.5	(20.8)
Hydropower	19.4	(2.9)	20.7	(2.4)
Coal/Coke	19.3	(2.8)	74.9	(8.7)
Charcoal	—	(—)	—	(—)
Fuelwood	58.9	(8.7)	78.0	(9.0)
Palm oil mill wastes	38.3	(5.6)	47.8	(5.6)
Total	679.6	(100)	863.1	(100)

¹ 1 Petajoule (PJ) = 10¹⁵ Joule (J)

BIOGAS FROM PALM OIL MILL EFFLUENT

The palm oil industry in Malaysia is expanding rapidly, as reflected in the increase in the number of palm oil mills in operation from 122 in 1977 to 210 in 1984. The area planted with oil palm has increased nearly three-fold in the last decade, from 219,000 hectares in 1970 to about 1.5 million hectares at present.

As a result, the production of crude palm oil has increased to 4.5 million tonnes in 1986, nearly 40 times that in 1960 when the industry was still in its infancy. This ranks Malaysia as the largest producer of palm oil in the world, accounting for over 60% of the total world production.

The process to extract oil from the fresh fruit bunches (FFB) requires a large amount of water, mainly for sterilizing the fruits and for oil clarification, resulting in the discharge of about 2.5 tonnes of effluent per tonne of crude oil processed.² Thus in 1986, about 11 million tonnes of effluent were generated from the local palm oil industry.

Fresh palm oil mill effluent (POME) is a brownish, colloidal suspension characterized by high contents of organics, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and solids (Table 3). As it leaves the factory, it has a temperature of 80–90°C and is acidic in nature. It has been estimated that POME contributes a BOD load of 640 tonnes per day to the aquatic environment, equivalent to a population of about 14 million people.⁴ It is therefore one of the major sources of pollution in the country.

Anaerobic digestion is a versatile biological treatment process yielding methane as a useful biomass energy. Early studies on the anaerobic treatment of POME concentrated on the mesophilic conventional process without solid recycle. Digesters currently in use commercially are all of the conventional type operated with relatively long hydraulic retention time (10–20 days) to provide the high bacterial retention required for methanogenesis.⁵ Anaerobic digestion carried out at thermophilic temperature is known to be superior to that at mesophilic conditions. The high temperature of raw POME is therefore an asset to be exploited. Recent years have seen considerable research efforts in this direction.

With depleting conventional energy resources, biogas from anaerobic digestion of POME is becoming an important source of alternative energy. This, coupled with increasing stringent discharge standards, has prompted research aimed at higher efficiency and lower costs.

Anaerobic fermentation of POME brings prolific gas yield and under thermophilic conditions it exceeds those from a number of other waste substrates.⁶ Table 4 compares the gas yields from POME digested at different substrate

loadings and reaction temperatures.⁷ It is evident that both the gas yield and methane content of the gas increase with increase in temperature at comparable BOD loading and hydraulic retention time. The contact process is, however, superior to the conventional process in terms of gas production.

TABLE 3
CHARACTERISTICS OF RAW PALM OIL MILL EFFLUENT AND
DEPARTMENT OF ENVIRONMENT (DOE) STANDARDS
FOR ITS DISCHARGE

Parameter ^(a)	POME ^(b)	DOE Standards ^(c)
Biochemical oxygen demand (BOD), 3 days at 30°C ^(d)	25,000	100(50) ^(e)
Chemical oxygen demand (COD)	53,600	-
Total solids (TS)	43,600	-
Suspended solids (SS)	19,000	400
Volatile solids (VS)	36,500	-
Oil and grease (O&G)	8,400	50
Ammoniacal nitrogen (NH ₃ -N)	35	100 ^(f)
Total Kjeldahl nitrogen (TKN)	770	200 ^(f)
pH	4.0	5.0 – 9.0
Temperature, °C	80 – 90	45

(a) All parameters, except pH and temperature, are expressed in mg l⁻¹

(b) Source : Ref (3)

(c) Effective since 1 January 1984

(d) Incubation conditions as stipulated in Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977, Government of Malaysia

(e) This additional limit is the arithmetic mean value determined on the basis of a minimum of four samples taken at least once a week for four weeks consecutively.

(f) Value on filtered sample

TABLE 4
GAS YIELD FROM BIOGASIFICATION OF POME

Anaerobic process	Temp. °C	Hydraulic retention time, d	BOD loading $\text{kgm}^{-3}\text{d}^{-1}$	Gas yield m^3kg^{-1} BOD used	CH ₄ %
Contact	60	6.7	3.01	1.47	69
	55	6.0	3.26	1.60	64
	50	4.7	3.44	1.13	63
	45	5.9	3.11	1.00	60
	38	10.0	2.90	0.90	58
Conventional	55	5.0	5.64	0.50	—
	55	15.0	1.88	1.16	—
	44–52	10–17	1.8–3.0	0.98–1.05	54–70
	38	25.0	1.2	0.97	58

About 28 m³ of biogas is produced for every cubic metre of POME treated. Hence in 1986 about 316 million cubic metres of biogas could be produced if this biomass energy scheme was put into operation.

In Malaysia cogeneration is widespread in the agricultural sector. Most of the palm oil mills have practised cogeneration ever since their inception. The locations of such mills are normally far from the national grids. Due to the abundant biomass products during their manufacturing process, an integrated cogeneration facility has been adopted using the waste products as the source of fuel.

Biogas produced from the anaerobic digestion of POME has been successfully utilized for heat and electricity generation.^{8,9} The two schemes of operation are as follows :

1. Heat generation

Biogas from a palm oil mill is piped directly to an adjacent rubber factory for use in a dual-fuel burner for the drying of rubber. Previously diesel oil was used as the sole fuel. The operation is simple, requiring only a booster fan to ensure that the biogas pressure at the burner inlet is 15–25 cm water. A pressure switch deactivates the booster fan should the gas holder pressure fall below a set level.

2. Electricity generation

Biogas from the anaerobic reactor is first scrubbed to reduce H₂S to less than 1,000 ppm using iron waste and wood shavings; this is necessary to

prevent corrosion in the gas engine. The scrubbed gas is then compressed and stored in a 42 m³ pressure vessel at a maximum pressure of 2.1 kg cm⁻². The biogas pressure is throttled to 0.8–1.4 kg cm⁻² before entering the gas engine which has a capacity of 252 kw. It is turbo-charged and after-cooled has a high compression ratio of 10:1. Cooling water for the gas engine is provided by a cooling tower. Pressure switches deactivate the biogas compressor should the pressure in the digester fall below, or the pressure in the pressure vessel exceeds set levels. The electricity generating system was commissioned in May 1982 and has been operating for over 10,000 hours, producing more than 2 million kwh of electricity. The operation has not encountered any major problem. As the gas engine consumes only 16% of the biogas produced, plans are being formalized to utilize the remaining gas for a separate manufacturing operation. It is estimated that for a mill discharging 576 m³ of POME per day, the costs for producing 1 m³ of biogas and 1 kwh of electricity are M\$0.13 (US\$0.05) and M\$0.0775 (US\$0.03) respectively, if the mill is operating at 66% utilization rate.

Recently, a steam cycle system for electricity generation has been proposed as an alternative to the internal combustion engine described above.¹⁰ Biogas and solid wastes are combusted in a boiler system to produce steam which drives a turbo-alternator to generate electricity. The exhaust steam can be tapped for use in the mill.

It has been estimated that the total electricity that could be obtained from POME throughout Malaysia is 568 million kwh which represents about 5% of the national grid demand. Biogas from anaerobic digestion of POME is therefore an immense source of renewable energy to be tapped.

BIOGAS FROM LIVESTOCK WASTES

In recent times, the traditional livestock rearing industry in Malaysia has become more organized and coordinated. Farms are becoming larger in size and complete disposal of a concentrated manure within the confines of the farms has become increasingly problematical. There exists in the country a fair number of such livestock farms where biogas technology can be introduced.

Applied research and some promotional work on biogas technology are presently being undertaken by some research institutes, universities and government agencies.¹¹ The biogas digesters that have been promoted relating to the biogasification of animal wastes and chicken droppings are basically of the Indian and Chinese designs with some modifications, typically ranging from 5 to 20 cubic metres in volume. Red mud plastic methane converter systems have also been introduced. In some cases the biogas has been used to run generators for supplying electricity to farm quarters and offices.

From an environmental and social view point piggery wastes stand out prominently as the most problematic of all livestock wastes where urgent attention has to be directed to seek immediate solution of treatment.¹² In 1984 there were 5,335 pig farms in Peninsular Malaysia with standing number over 1.46 million heads.¹³ It is in this sector where biogas technology can be introduced to fulfill the dual role of treatment and energy generation.

It is estimated that the potential biogas available per year from the livestock sector is about $5.5 \times 10^8 \text{ m}^3$ or 15.2 PJ.

BIOMASS OXYGENATED FUELS

The role of liquid fuel substitutes for diesel fuel and gasoline has been the subject of tremendous interest in the context of the Malaysian supply and demand for liquid fuels in the transportation sector.¹⁴ It is worthwhile noting that the energy demand by the transportation sector, mainly in the forms of diesel fuel and gasoline, was about 17.5% of total energy consumed in 1985. It is readily recognized that liquid forms of fuel will continue to play a dominant role in the transportation sector by virtue of their ease of delivery, storage and usage. In Malaysia some of the most promising fuel alternatives are petroleum gases, methanol or synthetic gasoline derived from methanol. It has been optimistically viewed that alcohols, methanol in the next decade or so and ethanol in the long run, hold the key to our liquid energy problems.

Ethanol production via fermentation is state-of-the-art technology for sugar and starch feed stocks. The use of non-food sources such as agro-industrial wastes and cellulosic materials is not fully developed.

The scope for the production of biomass ethanol for energy uses in Malaysia has been assessed in the context of utilization of locally available carbohydrate resources such as sago, cassava and other agricultural products and wastes.¹⁵

Sugar cane ventures in Malaysia have not been promising in the past where agronomic solutions have to be found before cane sugar can make any significant impact as a potential source of fermentable sugar. The area devoted to sugar cane growing is about 13,000 hectares in 1986.

The area devoted to tapioca is presently estimated at 5,000 hectares. The existing tapioca grown may be sufficient to supply the need for food and feed but it is rather too small a scale for biomass alcohol production. Tapioca is a hardy crop which could be grown on land where other crops may not grow. To optimize land utilization a possible alternative site for large scale tapioca growing and alcohol production is the bris soil land which exists along the states of the East Coast of Peninsula Malaysia where bris soil land is estimated at 170,000 hectares. Trials conducted on the growing of tapioca showed that bris

soil could be used for tapioca cultivation. Tapioca supply could be further supplemented by growing it as an intercrop at the early growing stages of perennial crops such as oil palm, rubber and coconut.

However, the greatest potential in the fuel plantation is in Sarawak which is recognised as the largest commercial sago starch producer in the country which in 1984 exported some 22,000 tonnes of sago starch valued at about M\$8.5 million (US\$3.3 million). The average annual volume of export during the period 1975 to 1984 was 24,000 tonnes with an average export value of M\$7.8 million (US\$3.0 million) annually. Sarawak has 1.5 million hectares or 12% of the total land area under peat soils. Sago palms thrive naturally on the coastal peats, but their exact area is not known. According to planimetric measurements in 1966, 22,700 hectares or 1.5% of the total peat area were under semiwild sago palms.¹⁶ Sago when grown in the wild condition is less productive and produces about 6-10 tonnes of starch per hectare but under cultivated system the production is expected to be higher, amounting to 22 tonnes per hectare. The major disadvantage with sago is that it has a long maturing period of about 8-10 years before the plant could be harvested. However, its advantages are that it needs very little care and fertilizer applications during its growth period and requires no further planting once it has established the colony.

The agro-industrial wastes (Table 1) are potential sources of fermentable sugars. However, these are mainly mixtures of cellulose and ligno-cellulose which make hydrolysis difficult. It has only been in the past 25 years that celluloses of microbial origin have been intensively studied to look into the possibility of hydrolysis of cellulosic materials. The potentially realisable ethanol from these agro-industrial wastes is estimated at 1.8 million tonnes.

Development of non-petroleum oxygenated fuels such as ethanol and mono-esters derived from vegetable oils has been a subject of global interest and activity.¹⁷ The derived mono-esters are much closer to conventional diesel fuels both in viscosity and in distillation characteristics. The evidence emerging from engine and service testing is that these durability problems on engines and fuel systems are much less serious than with the parent oils.

Vegetable oil fuels projects have attracted government support in several countries and Malaysia is no exception. Palm oil is in the second place of the world vegetable oil production and the rapid increase in the production of palm oil requires the expansion of its end uses. The Palm Oil Research Institute of Malaysia (PORIM) has successfully produced diesel palm oil and subsequently launched a palm oil diesel pilot plant in November 1985. This is expected to provide an alternative economic use of palm oil as a renewable source of energy.

HEAT AND POWER PRODUCTION FROM SOLID BIOMASS

Biomass energy has been one of the economic factors contributing to the flourishing palm oil industry in the country. All the palm oil mills use fibre and shell as boiler fuel to produce steam for palm oil extraction processes and electricity generation. Fibre and shell alone could generate more than enough energy to meet the palm oil mills' energy demand. In 1985 the Malaysian palm oil mills processed about 20.65 million tonnes of fresh fruit bunches (FFB) which would require about 413 million kwh of electricity equivalent for the palm oil production processes. This represents about 3.3% of the national electricity demand. It is estimated that about 0.34 litre of diesel is required to generate 1 kwh of electricity by diesel generation. Thus the fuel value of fibre and shell is equivalent to about 140 million litres of diesel which at M\$0.50 per litre would amount to about M\$70 million.¹⁸

Apart from fibre and shell, the empty fruit bunch (EFB) is another valuable solid biomass which can be used as an energy source. Presently only a small proportion of it is being used as fuel because pretreatment of the EFB is required due to its bulkiness and high moisture content (65%). Presently in most palm oil mills, the EFB is incinerated for potash-rich ash which is used as a fertilizer. In order to render it more easily combustable the EFB has to be shredded and dehydrated to a moisture content below 50%. The EFB has a heat value of about 1950 kcal/kg at 50% moisture content. Thus if all the EFB is used as an energy source its potential heat energy available in 1985 would be 8833×10^9 kcal. This would be sufficient to generate about 9.26 million tonnes of steam at 65% boiler efficiency and 308 million kwh electricity. This will contribute to a national saving of 104 million litres of diesel valued at M\$52 million. The argument will equally apply to other biomass such as palm trunks and fronds which, of course, would require more intensive pretreatment before they can be conveniently exploited.

Rice husk is the largest milling by-product of paddy. Based on a husk value of 20% and a calorific value of 3,000 kcal/kg the potential energy from rice husk as based on an annual availability of 380,000 tonnes is approximately $1,140 \times 10^9$ kcal. As a very low-valued product its low bulk density favours on-site treatment at the mills. The relatively high moisture content, especially paddy harvested in the wet season, presents considerable problems for incineration. In addition the high ash content remains a problem to be resolved satisfactorily and economically, especially when the husk contains fine silica particles which tend to form slags when incinerated about 1,000°C.

The rice milling industry is another example where cogeneration can be adopted. In Malaysia almost all the rice mills use electricity or diesel engines for their power requirement. Attention should therefore be directed to the develop-

ment of large husk-based heat and electrical generators to harness this source of energy as a practical and economic substitute to existing power sources.

Two 350 kw cogeneration systems have been successfully commissioned in 1983 at the rice milling complexes at Jerlun and Teluk Kechai, both in the state of Kedah, belonging to the National Rice Board or Lembaga Padi Negara (LPN). Each power plant is designed principally to utilize 1 tonne/hr of rice husk. The heat production from the burning of rice husk converts the water to steam for electricity generation via a single stage turbine and the exhaust steam from the turbine is used for drying paddy in the rice dryer complex.¹⁹

The benefits to be derived are expected from their own supply of electricity, displacing fuel oil in their heating requirements using the low process steam, potential sales of their rice husk ash produced and revenue from the sales of surplus electricity to the National Electricity Board (NEB). Based on the design of the cogeneration facilities at each of the milling complex, the LPN is expected to save about M\$200,000 on electricity and M\$85,000 on fuel bills annually.²⁰

CONCLUDING REMARKS

Unprecedented worldwide energy crises in the past triggered by the astronomical rise in oil prices have changed the fabric of global economic balance and impressed upon both developed and developing countries the need to conserve and optimize energy supplies. In these changed circumstances, particularly in developing countries, the use of forestry, agricultural and livestock residues, which are enormous in weight and volume, is economically very attractive as a source of biomass energy in localized situations. In Malaysia the potential energy realizable from these biomass resources is estimated to exceed 15% of the national energy needs. While constraints in the utilization of the biomass residues such as seasonal availability, geographic distribution, economics, availability of appropriate energy technologies, cultural and social acceptance, can be recognized, the country can ill-afford to ignore the pressing need for effective utilization of all energy resources for her energy economic well-being.

Rice husk has been identified as a potential biomass energy resource for the rice-milling operations in terms of in-situ heat and electricity generation for use within the mill or nearby industrial operations. While reducing the running cost of operation of rice mills through utilization of the husk for energy generation, it has the added advantage of reducing the pollution problem posed by the accumulation of husk within the vicinity of the mills.

Palm oil mill effluent has been proven as an excellent substrate for the anaerobic digestion process and treatment of the waste on a commercial scale is technologically and economically feasible. Biogas as a useful by-product of

the process can be harnessed for heat and electricity generation. With depleting conventional energy resources, the immense value of POME as a source of biomass energy should be fully exploited. Palm fibre, shell and the empty fruit bunches are potential biomass energy resources which through innovative and adaptive research and development efforts can further enhance their contributory role in national economic development.

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