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TECHNO-ECONOMIC ISSUES OF BIOMASS BASED COGENERATION IN A PALM OIL MILL OF MALAYSIA: A CASE STUDY

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ABSTRACT

Malaysia is the world's largest producer and exporter of palm oil. The palm oil biomass contributes more than 65% of the total available biomass potential in Malaysia. Only 5.4 percent of this potential is used to generate electricity while the other huge amount of process wastes bring about tremendous disposal and environmental problems. The amount of electrical power obtainable from biomass generated palm oil mill which includes empty fruit bunches, fibers, fruit shells and the waste effluent is quiet substantial. This paper describes the case studies of techno-economic issues of effective utilization of biomass energy at Rantau Oil Palm Mill located in Rantau, Negeri Sembilan, Malaysia. Efforts have been made to maximize utilization of the energy resources of palm oil mill to improve the overall production efficiency. Studies have been made to select the most suitable cogeneration system for the effective utilization of the biomass energy.

Keywords: *Biomass, Techno-economics, Cogeneration, Palm oil mill, Heat-power ratio.*

1.0 INTRODUCTION

The oil palm industry in Malaysia started around 1917, where the production of the oil palm grew very slowly. The impetus to expand and become more famous in the late 1950s when the government encourage the major crop diversification from rubber trees to oil palm. Malaysia, replacing the Nigeria as the chief producer and becomes the world's largest producer and exporter of palm oil since 1971. The success of the Malaysia palm oil industry is the result of the ideal climatic conditions, efficient milling and refining technologies, research and development facilities in many organizations, like the former Palm Oil Research Institute of Malaysia (PORIM), now the Malaysian Palm Oil Board (MPOB), the

Palm Oil Registration and Licensing Authority (PORLA), the Malaysian Palm Oil Promotion Council (MPOPC) and the adequate management skills.

In Malaysia, there are around 305 palm oil processing mills [1]. The range of fresh fruit bunches (FFB) production capacity for the mills were varies from 10 million tonnes per hour to 100 million tonnes per hour. The average production capacity for the mills were in the range of 20 million tonnes per hour to 40 million tonnes per hour. The production capacity of the 131 palm oil mills in the West Coast of Peninsular Malaysia is shown in Figure 1. 59

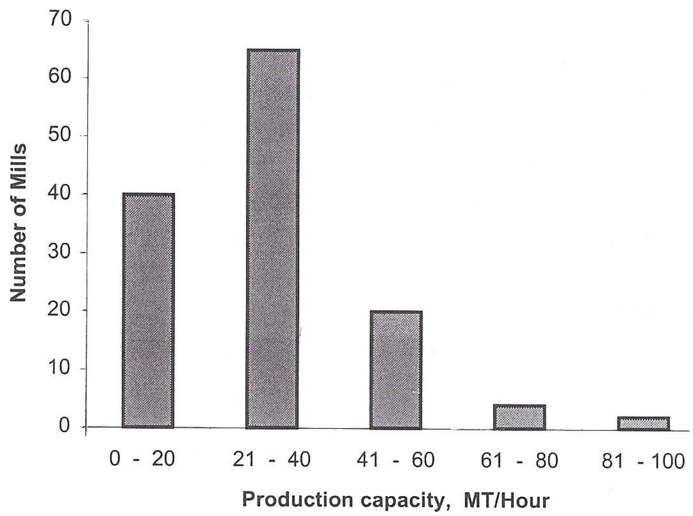

Figure 1 The production capacity for 131 mills of West Peninsular Malaysia

The total production of the palm oil in 1997 were about 9.062 million tonnes. The quantity of fresh fruit bunches (FFB) been processed in that particular year were about 43.2 million tonnes. In general, it is estimated that a 20 kWh of electricity were needed to process one tonne of FFB [2]. So, in 1997 the total power consumption for processing FFB were about 864,000 MWh. The potential electricity capacity that could be generated from the palm oil mills in 1997 were about 4,930.8 MW which can generate around 43,193,808 MWh of electricity if the oil palm wastes were fully utilized. The total annual power capacity (MWh) was obtained by assuming that the power plants are operating for 8760 hours per year. The details of the calculations were described in an earlier publication of the principal author [3].

2.0 OIL PALM BIOMASS

The oil palm biomass contributes more than 65 percent of the total available biomass potential in Malaysia. Only 5.4 percent of potential is used to generate electricity and there are large amount of process wastes which bring about tremendous disposal as well as environmental problems [4]. The palm fibres and the shells are used as a fuel for direct combustion in the boiler. The palm oil mill effluent (POME) and the empty fruit bunches (EFB) of the oil palm have been treated as fertilizer or animals feed. This POME and the EFB could be used as the fuel to generate electricity if utilised properly.

The main purpose of this study is to effective utilization of biomass energy of palm oil in the palm oil industry in Malaysia. The present works were carried out to find the optimum utilization of palm oil based biomass resources and minimize the cost of the palm oil production.

The analysis is performed based on data collected from the Rantau Oil Palm Mill located in Rantau, Negeri Sembilan, Malaysia. The mill was established in 1972. The total FFB production capacity of the mill is 40 million tonnes per hour and the number of employee is 130. The mill operates 22 hours daily for six days per week. Sometimes the mill operates 7 days a week depending on the supply of the fruits bunches. The total operating week for the year 1998 was 50 weeks. Information on steam and electricity consumption of the mill were collected through site visits and surveys via questionnaire.

2.1 Energy Consumption

The electrical and steam data for the year 1998 are as given below;

Electricity :

Maximum electricity consumption (July)	:	332.6 MWh
Minimum electricity consumption (January)	:	247.9 MWh
Maximum electricity demand (Peak)	:	740 kW
Minimum electricity demand (Base)	:	660 kW
Total electricity consumption for the year 1998	:	3,570 MWh

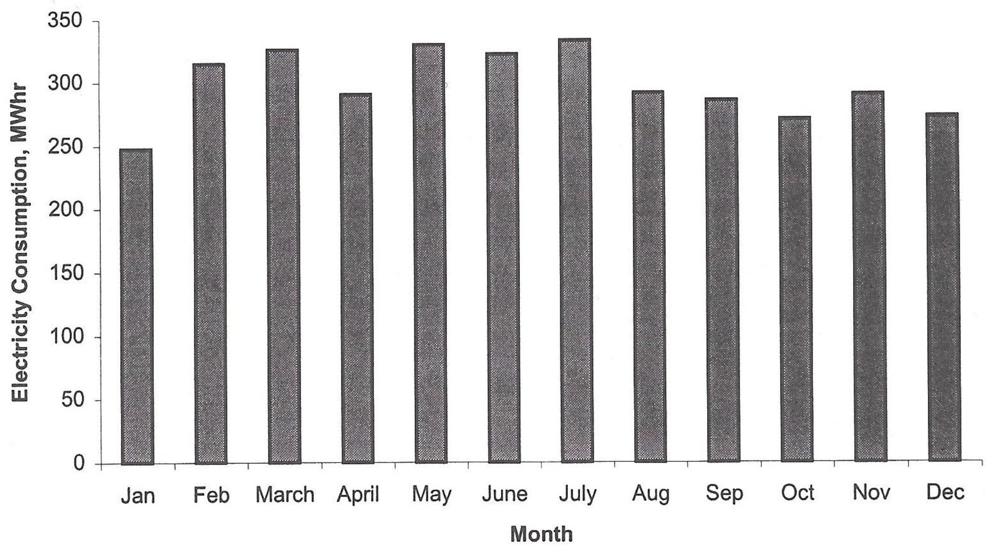

Figure 2 Electricity consumption for the year 1998 at Rantau Mill

<u>Steam Consumption:</u>

Maximum steam consumption (Peak)	:	19,240 kg/hr
Minimum steam consumption (Base)	:	17,160 kg/hr
Total steam consumption for the year 1998	:	42.84 TJ

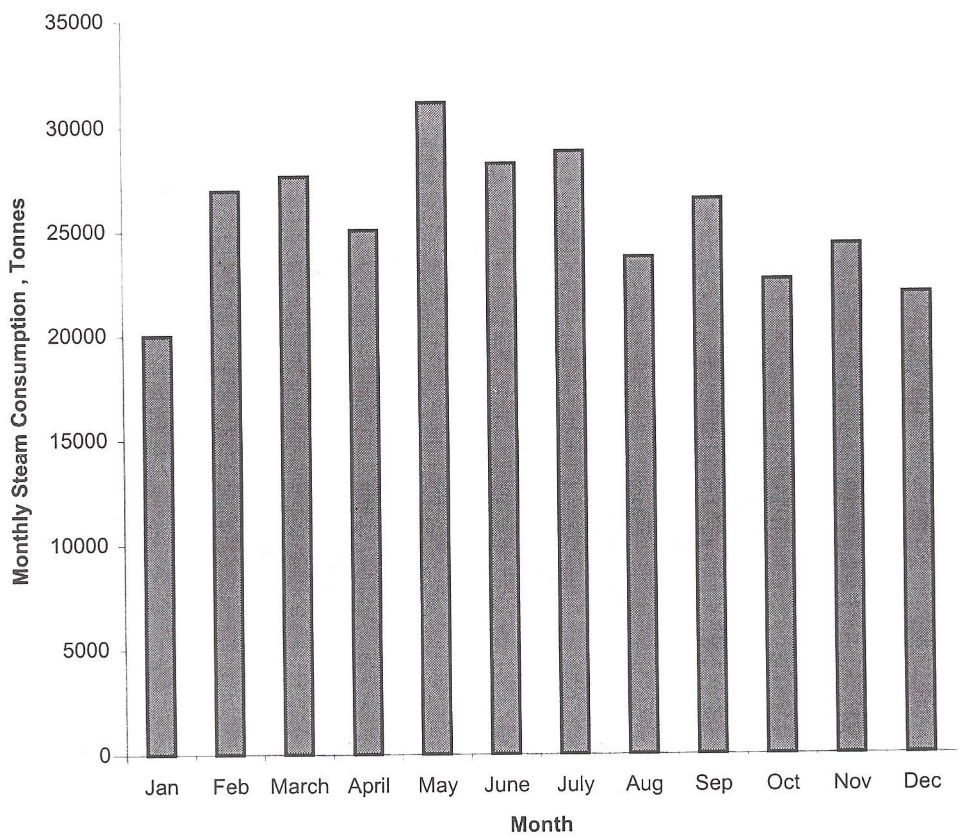

Figure 3 Monthly Steam Consumption for the year 1998 at Rantau Mill

2.2 Power to heat ratio

The palm oil mill requires both electricity and heat (steam) for the production process. The power station in a palm oil mill consists of boilers, deaerator heaters, feed water tank, steam engines or turbines and diesel. The ratio of energy consumption in the form of steam and electricity is called heat-power ratio. The obtained heat-power ratio of the mill is as follows:

Maximum power to heat ratio	:	0.32
Minimum power to heat ratio	:	0.29
Average power to heat ratio	:	0.30

2.3 Assumptions used in prefeasibility study

Assumptions used in the spreadsheet analysis are as follows [5]:

Exchange rate	RM / USD	3.8
Tax rate	% / year	35
Service life of the cogeneration plant	year	20
Purchased price of electricity	RM / kWh	0.18
Buy-back rate	%	80
Fuel price escalation rate	%	5-13
Electricity price escalation rate	%	6-13

Assumptions used in installation cost of a CHP plant:

For a steam turbine	:	RM 4560/kW
For a gas turbine	:	RM 3800/kW
For a reciprocating engine	:	RM 3420/kW

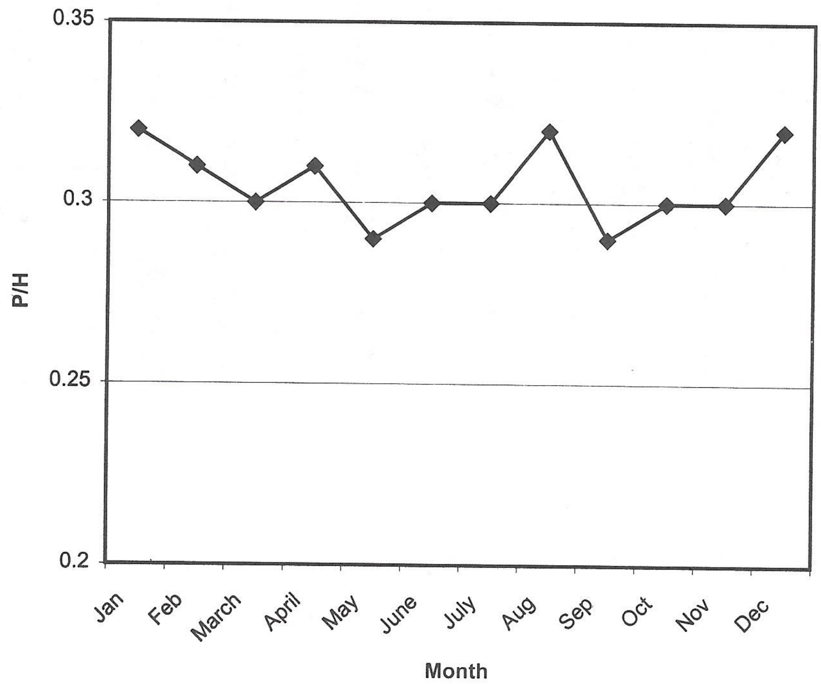

Figure 4 Power to heat ratio of Rantau Mill for 1998

The net present value (NPV) of cogeneration plant has been estimated as follows:

$$NPV = (CF)(AF) - (I)$$

$$AF = \frac{(1+i)^n - I}{i(1+i)^n}$$

where,
CF = cash flow for specific year
AF = annuity factor
i = discount rate
n = predicted economic life of the plant
I = investment

The NPV estimates the gain or loss resulting from the proposed investment. Therefore if NPV is positive the investment should be made become the relevant revenues exceed the financing cost. If NPV is negative the plant is not proposable.

3.0 METHODOLOGY

Data base on electricity demand, steam demand, annual electricity consumption annual thermal energy requirement were the initial inputs to the spreadsheet analysis [5]. The spreadsheet of its own estimates the related parameters required for cogeneration analysis. The steam turbine, reciprocating engine, gas turbine and also combination of steam and biogas turbine options with thermal match and power match results are shown in a computer print out of the spreadsheet analysis. The results also show the internal rate of return (IRR) on net investment for each option. Three alternatives were considered for sensitivity analysis as shown in Figures 5, 6 and 7. Figure 5 shows the changes of IRR with the equipment cost. Figure 6 and 7 show the effect of IRR with the fuel price and the electricity price respectively.

3.1 Common Data

Common data for the spreadsheet analysis are shown below ;

Power to heat ratio (required)	:	0.3
Actual operating hours	:	6,600 hours
Peak electricity demand	:	740 kW
Peak steam demand	:	19,240 kg/hr
Base electricity demand	:	660 kW
Base steam demand	:	17,160 kg/hr
Site electricity requirement	:	3,570 MWh
Thermal energy requirement	:	42.84 TJ
Fuel	:	biogas and solid biomass (fibers and shells)

4.0 DISCUSSIONS

From the spreadsheet analysis, with the gas turbine options, and the gas turbine thermal match (GTTM) options, about 20% of excess electricity has been generated. This is not acceptable because main purpose is not to earn from the electricity sale. Gas turbine power match (GTPM) option is also good because the deficit of heat is about 40 % which can be met by auxiliary boiler. The total installation cost of GTPM is 47% less than GTTM.

The steam turbine option does not seem to be considered for the sensitivity analysis because less than 40 % of the power requirement was generated with steam turbine thermal match. While with steam turbine power match 50% excess electricity 370% excess heat have been generated. Therefore the installed steam turbine for the mill is not the proper selection for both thermal and power match.

With reciprocating engine thermal match option 575 % excess power is generated. The project profitability depends on the buy-back rate. The reciprocating engine power match (REPM) seems does meet the power demand even though the heat generated is less than 73 % of the requirement.

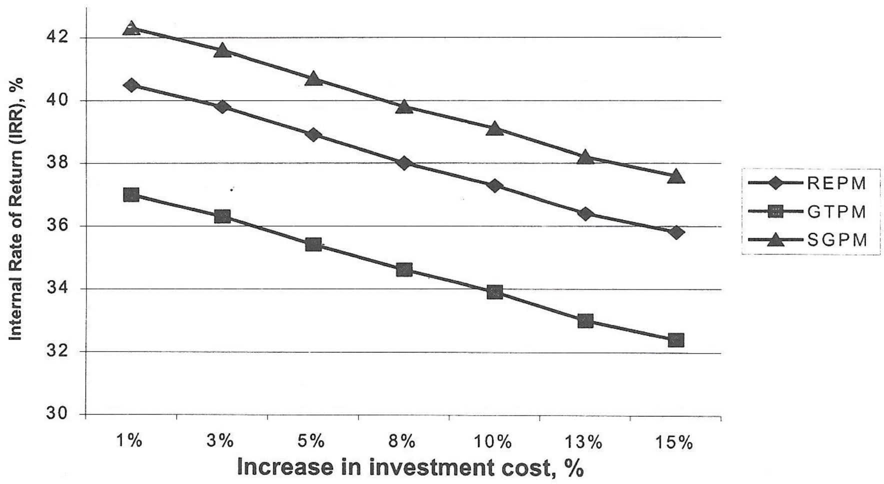

Figure 5 Effect of increasing the investment cost on IRR

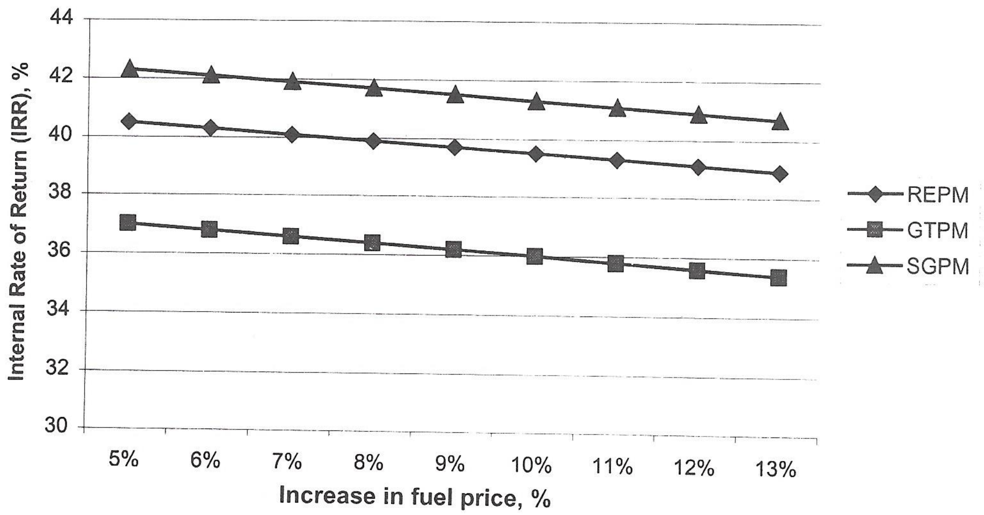

Figure 6 Effect of Fuel Price Escalation Rate on IRR

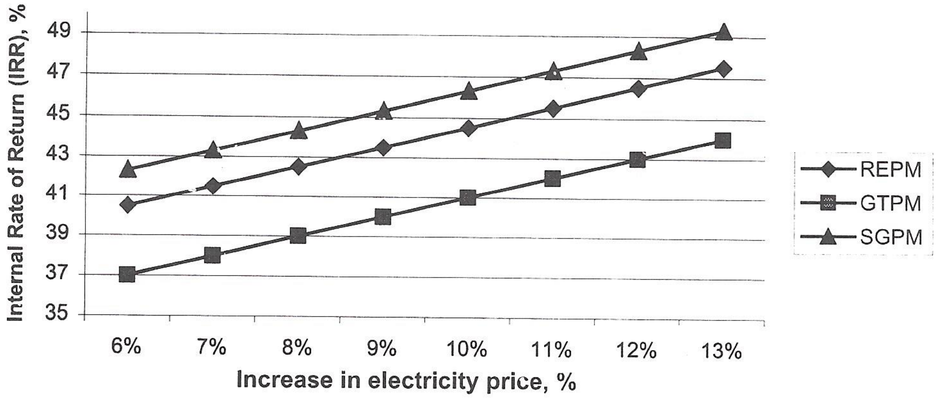

Figure 7 Effect of Electricity Price Increase on IRR

With the steam and gas turbine thermal match option, about 240 % excess power is generated which is not acceptable. Steam and gas turbine power match (SGPM) option seem to have excess electricity around 50 % but heat generated is less than 46 % of the requirement. Therefore, sensitivity analysis will be limited to REPM, GTPM, and SGPM options.

5.0 CONCLUSIONS

The potential cogeneration plant for the palm oil processing mill will be the combination of the steam and gas turbine which meet the power requirement of 660 kW. It represents an initial investment of RM5.52 million and leads to an internal rate of return around 42.3%. Further investigation can be made to increase the efficiency of the cogeneration system for grid connection.

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