Feasibility Study on the Potential Production of Oil Palm Shell Bio-phenol

Wong Chuan Chin*
and Farid Nasir Ani*

ABSTRACT

The extraction of bio-phenol from oil palm shell is being investigated in Universiti Teknologi Malaysia. In this article, the economic feasibility of producing oil palm shell bio-phenol is studied. Plants of three capacities – 100 t/day, 10 t/day and 1 t/day – are discussed. Their potential profitabilities are assessed, for which an estimation of the initial total investment and the cost of production were derived. The project evaluation and profitability analysis was performed including total capital investment, manufacturing cost, and discounted cash flow analysis. The plants require three years for starting up and their operating life is 17 years with a depreciation of 10% per year. The discounted cash flow rate of return (DCFRR) and the discounted break-even period (DBEP) are used to access the profitability. From the results, it shows that the bio-phenol extraction plants are feasible and profitable.

INTRODUCTION

Plant design engineers are frequently confronted with the problem of estimating the manufacturing cost of a product, especially for the equipment. The value of equipment cost should be a reasonable percentage to the total investment. In order to determine the investment accurately, it is necessary to carry out a detailed design and to submit the information to manufacturers for quotations. This step is time-consuming. It may just suffice to estimate the sizes of the various equipments required and then estimate their cost rather than call for quotations (Douglas, 1988).

Work has been done at Universiti Teknologi Malaysia to use oil palm shell as a renewable raw material to produce bio-phenols to diversify the palm oil industry to create more benefits for the country (Wong, 2003). In this study, three bio-phenol plants will be discussed. They are assumed to operate 24 hr/day and 330 days a year. Their outputs are assumed to be 100 t/day, 10 t/day and 1 t/day respectively. Their annual productions are, therefore 33 000 t, 3300 t, and 330 t respectively. All the designs are based on the results from the Simulator DESIGN II Version 8.35. DESIGN II is a simulator program to model a specific process on the information provided. In this article, only the 10 t/day plant is described in detail.

PROCESS ECONOMIC ANALYSIS

Following Douglas (1988), the equipment sizing and costing is based on the Guthrie design method. All the calculations are based on the results from the Simulator DESIGN II. The sizes,

* Faculty of Mechanical Engineering,
Universiti Teknologi Malaysia,
81310 UTM Skudai,
Johor, Malaysia.

capacities and cost of all the equipment in the simulation are determined.

Equipment sizing plays an important role in a plant design. It affects the profitability of the plant where the choice of materials used and the size of the units determine its feasibility (Coulson *et al.*, 1985). For this purpose, the flow rates, temperatures, pressures and heat duties from the simulation results are used in the calculations. Several assumptions are made on each type of unit before the sizing and costing are carried out, *i.e.* materials for construction, horizontal or vertical vessel, and ratio of length to diameter. The summary of the process equipment costs for the three production yields are shown in *Table 1*.

The first part of the economic evaluation was based on the exact cost of the equipment, followed by total capital and total production cost evaluation as the next step. The total of the exact costs is called fixed capital, that is, the capital invested in real equipment, not easily convertible to other forms of capital. Therefore, the bare module cost (CBM) and the total bare module cost (CTBM) for the whole plant should be obtained.

The bare module method is used to estimate the cost of equipment in the plant. All the equipment costs are used to determine the gross roof capital (GRC) cost for the plant. GRC makes up the major portion of total fixed capital cost (FCI).

TABLE 1. SUMMARY OF PROCESS EQUIPMENT COSTS (RM)

Equipment	1 t/day	10 t/day	100 t/day
Mixer	1 670	8 920	38 920
Extractor 1	5 770	28 855	134 450
Extractor 2	5 420	27 090	126 000
Flash separator	3 100	15 260	71 000
Condenser	10 300	60 610	270 940
Storage tanks (2 units)	27 200	112 200	380 200
Total bare module cost, CTBM, RM	53 460	252 935	1 021 510
Contingency and fees = 0.18 CTBM	9 620	45 528	183 870
Total module cost, CBM = 1.18 CTBM	63 080	298 463	1 205 380
Auxiliary facilities = 0.30 CBM	18 920	89 537	361 620
Gross–roof capital (GRC) = 1.3 CBM	82 000	388 000	1 567 000

TABLE 2. FIXED TOTAL CAPITAL AND INVESTMENT COST (10 t/day plant)

	Specification	Total (RM)
Direct cost		
On site		
Purchased equipment	30% GRC	116 400
Instrumentation and control	5% GRC	19 400
Piping (installed)	40% GRC	155 200
Electrical and material	5% GRC	19 400
Off site		
Building	30% GRC	116 400
Yard improvements	5% GRC	19 400
Service facilities	5% GRC	19 400
Land	40% GRC	155 200
Total 1	-	**620 800**
Indirect cost		
Engineering and supervision	10% GRC	38 800
Construction expenses	15% GRC	58 200
Contractor's fee	10% GRC	38 800
Contingency	10% GRC	38 800
Total 2	-	**174 600**
Total 3 = Totals (1 + 2)	-	795 400
Gross roof capital (GRC)	-	388 000
Fixed capital investment (FCI)	Total 3 + GRC	1 183 400
Working capital (WC)	10% FCI	118 340
Total capital investment (TCI)	FCI + WC	**1 301 740**

TOTAL CAPITAL COST

The total capital cost includes fixed capital and working capital. The total fixed capital investment includes the purchased equipment cost and installation, construction supervision, piping, instrumentation and control systems, buildings and structures, and

auxiliary facilities, *i.e.* utilities, land and civil engineering work. For the working capital, additional investment is needed to start up and operate the plant to the point of income being earned. This includes the cost of start up, raw materials intermediates in the process, finished product inventories and funds to cover the outstanding accounts from customers. The summary of capital costs for the 10 t/day production plant is shown in *Table 2*. The specifications in *Table 2* are average estimation based on cost data from 42 different projects (Ulrich, 1984).

TABLE 3. ANNUAL MANUFACTURING COST (3300 t/yr plant)

Manufacturing expense	Specification	Total (RM)
Direct production cost		
Bio-oil	6 000 t x RM 304/t	1 824 000
Ethyl acetate	1 330 t x RM 652/t	867 160
Sodium bicarbonate	300 t x RM 516/t	154 800
Water	11 500 m^3 x RM 2.36/m^3	27 140
Cooling water	8 355 m^3 x RM 2.36/m^3	19 718
Electricity	851 800 kWhr x RM 0.23/kWhr	195 914
Maintenance and repairs	6% of FCI	71 004
Operating supplies	1% of FCI	11 834
Operating labour	12 x 1 500 x 24	432 000
Direct supervision & clerical labour	10% of operating labour	43 200
Laboratory charges	15% of operating labour	64 800
Patents and royalties	5% of TCI	65 087
Total 1		3 776 655
Indirect product cost		
Overhead, storage	60% of operating labour	259 200
Local taxes	1.5% of FCI	17 751
Insurances	0.5% of FCI	5 917
Total 2		282 862
Total manufacturing expenses, AME	Total 1 + Total 2	4 059 517
General expenses		
Administration cost	25% of overhead	64 800
Distribution & selling expenses	10% of FCI	118 340
Research and development	5% of FCI	59 170
Total general expenses, AGE	-	242 310
Total production cost, APC	AME + AGE	4 301 827
Annual depreciation, ABD	10% of FCI	118 340
Total expenses, ATE	APC + ABD	4 420 167
Revenues from sales	RM 2 500 x 3 300 t/yr	8 250 000
Net annual profit, ANP	Revenues – ATE	3 829 833
Income taxes	30% of ANP	1 148 950
Net annual profit after taxes, ANNP	ANP – income taxes	2 680 883
Rate of return	$\frac{A_{NNP} + ABD}{TCI} \times 100\%$	215%

TOTAL PRODUCTION COST

After determination of the total capital cost, the plant operational and selling costs for the product have to be estimated. Generally, the total production cost is broken down into two components - manufacturing costs and general expenses. The manufacturing cost includes both direct and indirect production cost, general expenses and annual depreciation. Direct production cost includes the raw material cost, utilities, operating labour cost, maintenance and others. The annual manufacturing cost for 3300 t bio-phenol is shown in *Table 3*. The specifications of indirect product cost and general expenses in *Table 3* are the estimation values from reference (Ulrich, 1984). The cost of oil palm shell-based bio-oil is estimated as RM 304/t in year 1999 (Islam, 1999).

RATE OF RETURN

The plant is estimated to operate 330 days annually to produce 3300 t of bio-phenol. The expected rate of return is calculated below:

$$\text{Cost of producing phenol} = \frac{\text{RM 4 420 167}}{\text{3300 t}}$$

$$= \text{RM 1340/t}$$

As the price of petroleum phenol is around RM 5000/t, the bio-phenol is assumed to sell at half of the petroleum phenol price, RM 2500/t.

Revenue from sales
= RM 2500 x 3300 t
= RM 8 250 000

Annual profit
= revenue from sales – total expenses
= RM 8 250 000 – RM 4 420 167
= RM 3 829 833

Income tax is assumed at 30% of the annual profit
= 30% x RM 3 829 833
= RM 1 148 950

Net annual profit after income tax,

A_{NNP} = RM 3 829 833 – RM 1148 950

= RM 2 680 883

There are four different methods used by accountants to define the rate of return on the total capital investment. Following Ulrich (1984), the rate of return

$$= \frac{A_{NNP} + ABD}{TCI} \times 100\%$$

$$= \frac{RM\ 2\ 680\ 883 + RM\ 118\ 340}{RM\ 1\ 301\ 740} \times 100\%$$

= 215%

PAY BACK PERIOD (PBP)

The pay back period (PBP) is the time required to recover all the fixed capital investment from the start up of the plant. The plant life, *n*, is estimated to be 20 years, inclusive of the first three years construction. The undiscounted cash flow is shown in *Figure 1*, from which the pay back period can be seen to be 4.6 years, inclusive of the first three years set up period.

DISCOUNTED CASH FLOW ANALYSIS

The undiscounted cash flow analysis does not take account of the time value of money. Therefore, for a more realistic analysis, the annual cash flows are multiplied by a discount factor f_d appropriate to the year, *n* and interest rate, *i* in the formula,

$$f_d = \frac{1}{(1+i)^n}$$

To yield the cumulative discounted cash flow in terms of current Malaysian Ringgit, RM. The result would depend on the interest rate assumed, of which 15% and 73% were used. The assumed interest rate of 15% is higher than the present market interest rate because the inflation, risks or other unknown variables that may occur. When the net present value (NPV) becomes zero, the interest rate is about 73%. The new cash flow profiles are plotted in *Figure 2*. The discounted cash flow rate of return (DCFRR) takes into account the actual interest on the capital used for investment. Because of this, it is useful for comparing with alternate investments. The DCFRR should be higher than the interest rate, otherwise the project is not profitable. An interest rate of 15% was considered currently reasonable with which to assess the plant. From *Figure 2*, the discounted break-even period (DBEP) at 15% is about 5.0 years. The DCFRR is about 73%, which is much higher than the current interest rate of 15%. Thus, the project is feasible and profitable.

RESULTS AND DISCUSSION

The costings of these three phenol extraction plants are summarized

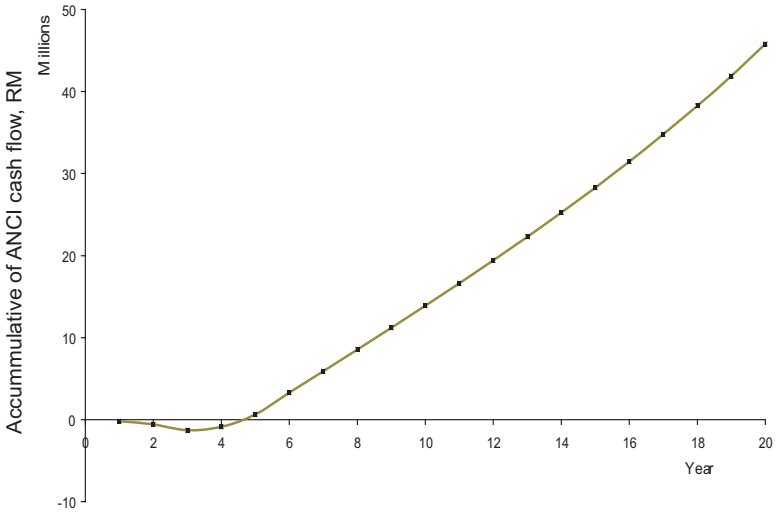

Figure 1. Cash flow for 10 t/day palm shell-based bio-phenol plant without discount rate.

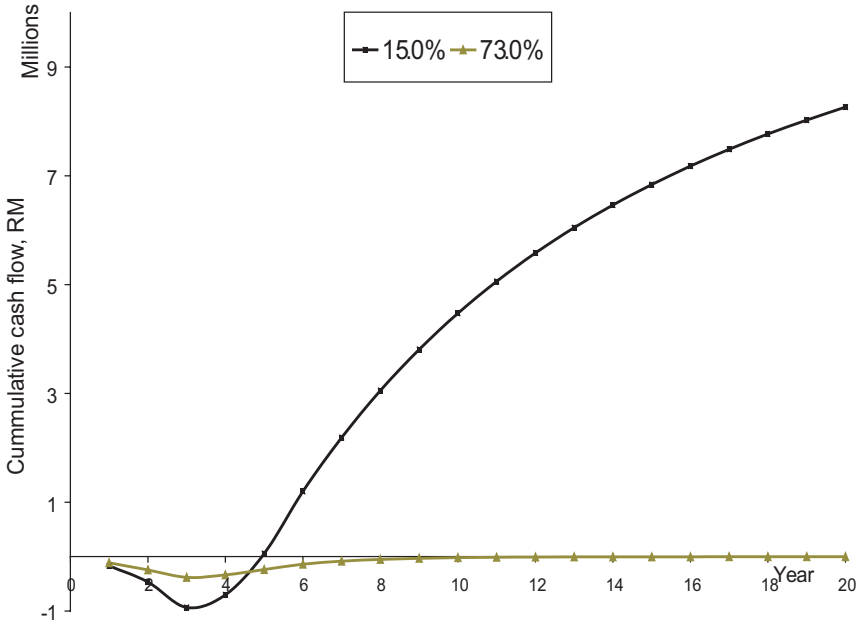

Figure 2. Cash flow for 10 t/day palm shell-based phenol plant with different discount rates.

TABLE 4. SUMMARY COSTING OF BIO-PHENOL EXTRACTION PLANTS

Specifications	1 t/day	10 t/day	100 t/day
Total capital investment, TCI (RM)	275 110	1 301 740	5 257 285
Annual total expenses, ATE (RM)	623 666	4 420 167	34 773 000
Annual revenue from sales, AS (RM)	825 000	8 250 000	82 500 000
Annual net profit after taxes, ANNP (RM)	140 934	2 680 883	33 408 900
Cost of OPS phenol per tonne (RM)	1 890	1 340	1 054
Pay back period, PBP	7.4 years	4.6 years	3.6 years
Discounted break-even period (DBEP)	10.3 years	5.0 years	3.7 years
Discounted cash flow rate of return, DCFRR	24.0%	73.0%	147.0%
Rate of return after taxes	60%	215%	645%

in *Table 4*. From both discounted and undiscounted cash flow analyses, their profitability can be accessed. The pay back periods of 3.6 years to 7.4 years can be considered reasonable for a plant life of 20 years. However, these values do not take into account the time value of money. Hence, the DBEP would be the more appropriate measure with which to access their profitability, taking into account the current interest rate. From the plants, the DBEP are 10.3 years, 5.0 years and 3.7 years, respectively – still very reasonable for a plant life of 20 years. The DCFRR has been determined to be 24%, 73% and 147%, respectively, which are high compared to the estimated current interest rate of 15%.

CONCLUSION

Concluding from the results, all the proposed 100 t/day, 10 t/day and 1 t/day bio-phenol extraction plants are feasible and profitable.

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LIST OF SYMBOLS

%	-	percent
f_d	-	discount factors
n	-	number of years
i	-	interest rate
t/day	-	tonne per day
t/yr	-	tonne per year
C_{BM}	-	bare module cost
C_{TBM}	-	total bare module cost
GRC	-	gross roof capital
FCI	-	fixed capital cost
TCI	-	total capital investment
WC	-	working capital
AME	-	total manufacturing expenses
AGE	-	total general expenses
APC	-	total production cost
ABD	-	annual depreciation
ATE	-	total expenses
ANP	-	annual net profit
ANNP	-	annual net profit after tax
PBP	-	pay back period
DBEP	-	discounted break-even period
DCFRR	-	discounted cash flow rate of return
NPV	-	net present value