

## **PART 3 – AROMA CHEMICALS from PETROCHEMICAL FEEDSTOCKS**

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### **12 TECHNO-ECONOMIC ANALYSIS**

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A techno-economic model to evaluate the basket of aroma chemicals has been developed. The objective of this model was to determine the optimum configuration of products based on the following considerations:

- The most attractive products as identified above.
- The key drivers as identified above.
- Specific pricing issues, e.g. for MP96 and m-cresol as raised during the benchmarking exercises.
- The economies of scale information for the pHB, pAA and vanillin plants derived by the benchmarking analysis.
- The relative competitiveness of the different processes vs the market leaders.

#### **12.1 Techno-Economic Model Assumptions**

The economic models were based on a number of assumptions. These are listed as follows:

1. The project has a lifespan of 15 years.
2. The production plant is non-site specific.
3. R/\$ exchange rate is calculated on the differential between the consumer price index in the USA and the core consumer price index in South Africa i.e. purchasing power parity is assumed.
  - The 2004 SAR/ US \$ exchange rate was assumed to be 7.00.
  - The SA and US inflation rates were assumed to be 6% and 1.5% respectively. These rates stay constant for the life of the project.
4. The fixed capital investments required for the project were based on the CSIR capital estimates.
  - Capital estimates were performed at different times. They were therefore adjusted accordingly.
  - Capital estimates exclude Outer Battery Limit services, utilities and infrastructure. The capital estimates were based on the cost of the individual main plant items, to which an installation factor was applied in order to arrive at a total installed cost. The factored estimate has an accuracy of  $\pm 30\%$ . A process development allowance factor was determined and applied to the fixed capital investment. The process development allowance is a process contingency, and is dependant on the status of the development of the technology.
5. The tax allowance on the fixed capital investment has been assumed to be at a fixed rate of 10% per annum (straight line) for 10 years,

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- commencing in the first year of production, and remains constant in nominal South African Rand terms for the lifetime of the project.
6. The current tax rate of 30% is used.
  7. The project's terminal value is equal to the value of the residual working capital in year 15. The commercial plant has no (scrap) value at the end of its lifetime.
  8. No technology license fee or royalty payment is included.
  9. Selling prices remain constant in nominal US\$ terms.

|                                    |            |
|------------------------------------|------------|
| (a) OMC price                      | \$10.00/kg |
| (b) pAA (technical grade)          | \$ 6.25/kg |
| (c) pAA (flavour grade)            | \$8.00/kg  |
| (d) pHB (technical grade)          | \$7.00/kg  |
| (e) Menthol (flavour grade)        | \$15.00/kg |
| (f) Vanillin (flavour grade)       | \$11.00/kg |
| (g) Ethyl vanillin (flavour grade) | \$23.00/kg |
  10. The raw material and utility requirements for the project were based on technical information received from the CSIR and Mbuyu Biotech for menthol.
  11. Long-term average prices for raw materials and products have been assumed. The cresol feedstock was assumed to be MP96, a non-commercially available mixed p- cresol and m-cresol stream. The feedstock has a typical p-cresol: m-cresol ratio of 47%:49% and a total purity of 96%.
  12. Variable costs remain constant in nominal US \$ terms.

|              |            |
|--------------|------------|
| (a) MP 96    | \$ 1.40/kg |
| (b) m-Cresol | \$1.80/kg  |
  13. Locally determined prices such as utilities and fixed costs remain constant in real terms over the life of the project.
  14. Utility prices are assumed to be AECI delivered in Richard's Bay prices.<sup>40</sup>
  15. Fixed costs have been determined using factor estimates based on those used in the fine chemical industry. Maintenance materials and labour are each assumed to be 2.0% of fixed capital. Site and general overheads are 1.2% of fixed capital, and selling and general overheads are 0.5% of turnover. These costs remain constant in real South African Rand terms for the lifetime of the project.
  16. An annual plant efficiency improvement was assumed in order to maintain constant operating margins.

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<sup>40</sup> The AECI study was performed on the basis of the plant being located at the AECI Alton Site Richard's Bay.

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### **12.2 Methodology**

Two different business models were analysed. The motivation for this approach is that it is possible that there may be a necessity to involve more than one player in the establishment of the value chain. This may come about as different investment partners, strategic partners, or marketing alliances are selected in order to add value at the different stages in the business. For example, a commodity type chemical company may have a stronger role to play in the upstream part of the value chain, whereas an association with a flavour and fragrance house may be the strategy chosen in the downstream businesses.

The consultant has therefore attempted to determine the set of conditions under which a number of business options can be made viable. The business options analysed are depicted graphically in Appendix 7.

**OPTION 1:** Fully integrated from the production of the Bulk Intermediates through to the manufacture of the final Aroma and Fine Chemicals. This analysis also determined the optimum product portfolio. (Company A)

**OPTION 2:** Using the optimised product portfolio as the basis for further analysis, the business was then divided into a Bulk Intermediate business (Company B) and an Aroma Chemical business (Company C).

### **12.3 Option 1: A Fully Integrated Aroma Chemical Plant**

The sales of all products to the merchant market from the integrated Aroma Chemical plant are at the world prices as described in section 12.1 (point 9) above unless specified otherwise.

#### **12.3.1 Determination of the pHB plant capacity**

In constructing the optimal product portfolio, it must therefore first be recognised that the size of the pHB plant will be determined by the size of the menthol plant. The key raw material for menthol is m-cresol, the natural arising from the oxidation of MP96 to pHB. Hence, the first step is to decide on the capacity of the menthol plant. The size of the menthol facility was elected to be 1,500 tons per annum as this was the capacity at which the Mbuyu Biotech assessment had been performed, and at which the information had been made available.

This capacity was deemed reasonable through study of the menthol market. Total menthol production i.e. natural and synthetic is in the order of 12,730 – 13,320 tpa. Of this capacity, synthetic menthol accounts for 2,700 tpa. Hence the proposed 1,500 tpa plant represents approximately 50% of existing synthetic capacity and 12% of the total capacity. In addition, it must be recognised, that synthetic menthol only finds

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application in certain market segments of the total menthol market i.e. the oral hygiene and cigarette sectors. These sectors represent a potential synthetic market of 4,600 tons (38% of the market).

Table 26 outlines the project return without any production of menthol assuming the pHB and pAA plants are at the minimum economy of scale i.e. 2,000 tpa. The assumption in this analysis was that all pHB produced was fully converted to technical grade pAA and that it is sold into the merchant market at the world price of \$ 6.25/kg. m-Cresol must then be sold into the merchant market.

**TABLE 26: Integrated plant without menthol**

| Real IRR (%) | m-cresol price (\$/kg) | Capital (R million) | pHB capacity (tpa) | pAA Capacity (tpa) | pHB Cash Cost (\$/kg) | pAA Cash Cost (\$/kg) |
|--------------|------------------------|---------------------|--------------------|--------------------|-----------------------|-----------------------|
| 0.9          | 1.80                   | 102                 | 2,029              | 2,063              | 4.25                  | 5.11                  |
| 5.9          | 2.30                   | 102                 | 2,029              | 2,063              | 3.74                  | 4.61                  |

If the plant does not produce any menthol, at a pAA capacity of over 2,000 tons per annum, the project has a real IRR of 0.9% selling m-cresol into the world market at \$ 1.80/kg. Selling m-cresol at \$ 2.30/kg will increase the real IRR to 5.9%. Over 2,000 tons of m-cresol will however have to be sold into the world market. The plant will therefore be competing with its feedstock supplier.

Table 27 outlines the project return (real IRR) of various menthol capacities, vs pHB and pAA capacities. This analysis was performed in order to determine whether at the chosen menthol capacity, the pHB and pAA plants would meet the economy of scale requirements, and whether the plant would have investment economics.

**TABLE 27: Menthol capacity vs pHB, pAA capacities and Project Return (m-cresol price \$ 1.80/kg)**

| Menthol Capacity (tpa) | Real IRR (%) | Capital (R million) | pHB capacity (tpa) | pAA Capacity (tpa) | pHB Cash Cost (\$/kg) | pAA Cash Cost (\$/kg) |
|------------------------|--------------|---------------------|--------------------|--------------------|-----------------------|-----------------------|
| 1,200                  | 17.2         | 178                 | 1,353              | 1,375              | 4.48                  | 5.26                  |
| 1,500                  | 19.2         | 207                 | 1,691              | 1,719              | 4.35                  | 5.17                  |
| 1,800                  | 20.7         | 235                 | 2,029              | 2,063              | 4.25                  | 5.11                  |

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At a menthol capacity of 1,500 tons, the project return increases to 19.2% even though at this menthol capacity, the pAA plant is below the economy of scale indicated in the benchmarking exercise.

The pHB capacity was therefore determined to be 1,691 tons, the pAA capacity 1,719 tons and the menthol capacity to be 1,500 tons. These capacities will be used as the basis for further analysis.

### **12.3.2 Determine the mix of PAA, OMC, vanillin and ethyl vanillin**

The determination of the optimum mix of the aroma chemicals and personal care ingredients listed above was performed by introducing each product individually into the plant as described above in section 12.3.1 i.e. pHB 1,691 tons; pAA 1,719 tons; and menthol 1,500 tons.

- **Para Anisaldehyde**

The pAA market is in the order of 4,500 tpa of which 2,100 tpa is sold for conversion into OMC market. Clearly, to compete in the pAA market, a producer must sell a substantial quantity of product to an OMC producer. The benchmarking exercise concluded that OMC producers require pAA at a price of \$ 4.80 - 5.50/kg in order to compete with the market leader BASF on a cash cost basis (see section 5.2.1 above). The cash cost of the integrated pAA producer as outlined above is below these prices. Table 28 below indicates the project IRR should the South African producer sell pAA to the merchant market at these prices in comparison to selling it at market related prices.

**TABLE 28: pAA price vs Project Return**

| <b>PAA price (\$/kg)</b> | <b>Real IRR (%)</b> | <b>% of Base Case</b> |
|--------------------------|---------------------|-----------------------|
| 4.80                     | 15.4                | 76%                   |
| 5.50                     | 17.2                | 88%                   |
| 6.25                     | 19.2                | 100%                  |

An integrated pAA plant, selling product to the merchant market at world price in the range of \$ 4.80 - 6.25/kg clearly has investment economics. However, reducing the price to the levels required by an OMC to remain competitive would be coupled with a substantial loss in value although the plant will still attain investment economics.

- **Octylmethoxycinnamate**

Table 29 shows the effect on the project return by producing OMC in addition to pHB, pAA and menthol at the capacities determined in section 12.3.1.

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**TABLE 29: OMC capacity vs Project Return**

| OMC capacity (tpa) | Real IRR (%) | Capital (R millions) | PHB capacity (tpa) | PAA capacity (tpa) | PAA sold (tpa) |
|--------------------|--------------|----------------------|--------------------|--------------------|----------------|
| 0                  | 19.2         | 207                  | 1,691              | 1,719              | 1,719          |
| 1,200              | 22.1         | 238                  | 1,691              | 1,719              | 1,042          |
| 2,000              | 24.8         | 247                  | 1,691              | 1,719              | 591            |
| 2,800              | 27.4         | 256                  | 1,691              | 1,719              | 140            |

It can be seen therefore that producing OMC adds substantial value to the project. The amount of OMC that can be produced however will be influenced by how much can be absorbed by the market. The OMC market is estimated to be in the order of 5,500 tpa. Symrise, the largest competitor to BASF has a capacity of 2,000 tpa. BASF itself has a capacity of 4,500 tpa but is estimated to sell in the order of 2,100 tpa. The maximum OMC capacity that could be produced is therefore considered to be 2,000 tpa.

- **Vanillin**

The vanillin market is in the region of 10,500 tpa. The minimum economy of scale as determined in the benchmarking exercise was 1,000 tpa. Table 30 lists the impact of introducing different vanillin capacities in addition to pHB, pAA and menthol at the capacities determined in section 12.3.1 on the project return. pHB not converted into vanillin is converted into pAA and sold at the world price i.e. \$6.25/kg.

**TABLE 30: Vanillin Capacity vs Project Return**

| Vanillin Capacity (tpa) | Real IRR (%) | Capital (R millions) | Vanillin Cash Cost (\$/kg) | pHB Capacity (tpa) | pAA Capacity (tpa) |
|-------------------------|--------------|----------------------|----------------------------|--------------------|--------------------|
| 0                       | 19.2         | 207                  |                            | 1,691              | 1,719              |
| 500                     | 14.2         | 254                  | 11.68                      | 1,691              | 1,187              |
| 1,000                   | 12.0         | 280                  | 11.15                      | 1,691              | 656                |
| 1,500                   | 10.3         | 305                  | 10.89                      | 1,691              | 125                |

This table shows clearly that introducing vanillin into the product portfolio detracts value. Vanillin makes a marginal positive contribution at a capacity over 1,500 tpa. The contribution margin for pAA is higher than that of vanillin, hence as the vanillin capacity increases, the pAA capacity decreases and the project return decreases.

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Overall, although the project does make a positive return and can have investment economics if vanillin is included in the portfolio, it makes more economic sense to convert as much pHB *via* pAA through to OMC.

The question however has been asked as to whether or not a scenario could be defined under which vanillin could be added to the portfolio without detracting value. The analysis in section 5.3.3 demonstrated that a South African vanillin producer would have a cash cost of production closest to that of the market leader Rhodia, if finance charges were not included. Hence, the analysis above was repeated assuming that no capital expenditure is required in order to produce vanillin.

**TABLE 31: Vanillin Capacity vs Project Return assuming no capital expenditure**

| Vanillin Capacity (tpa) | Real IRR (%) | Capital (R million) | Vanillin Cash Cost (\$/kg) |
|-------------------------|--------------|---------------------|----------------------------|
| 0                       | 15.6         | 207                 |                            |
| 500                     | 18.1         | 198                 | 10.56                      |
| 1,000                   | 17.7         | 192                 | 10.25                      |
| 1,500                   | 17.0         | 189                 | 10.89                      |

In this scenario, when no additional capital expenditure is required, the project still has a lower return than if vanillin were not produced. Although, at 1,500 tons vanillin now makes a positive contribution, the contribution for pAA is higher.

- **Ethyl Vanillin**

The ethyl vanillin market is in the region of 1,700 tpa. The minimum economy of scale as determined in the benchmarking exercise was 1,000 tpa. Table 32 lists the impact of different ethyl vanillin capacities on the project return. pHB not converted into ethyl vanillin is converted into technical grade pAA and sold at \$6.25/kg.

**TABLE 32: Ethyl Vanillin Capacity vs Project Return**

| Ethyl Vanillin Capacity (tpa) | Real IRR (%) | Capital (R millions) | Ethyl Vanillin Cash Cost (\$/kg) | pHB Capacity (tpa) | pAA Capacity (tpa) |
|-------------------------------|--------------|----------------------|----------------------------------|--------------------|--------------------|
| 0                             | 19.2         | 207                  |                                  | 1,691              | 1,719              |
| 500                           | 15.5         | 254                  | 21.14                            | 1,691              | 1,200              |
| 1,000                         | 14.5         | 281                  | 20.62                            | 1,691              | 682                |
| 1,500                         | 13.8         | 305                  | 20.36                            | 1,691              | 163                |

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Ethyl vanillin clearly also detracts value from the project. Hence, as in the case of vanillin, it was determined to what extent ethyl vanillin could add value to the portfolio if no new capital was required.

**TABLE 33: Ethyl Vanillin Capacity vs Project Return assuming no capital expenditure**

| Ethyl Vanillin Capacity (tpa) | Real IRR (%) | Capital (R million) | Ethyl Vanillin Cash Cost (\$/kg) |
|-------------------------------|--------------|---------------------|----------------------------------|
| 0                             | 19.2         | 207                 |                                  |
| 500                           | 19.35        | 198                 | 20.01                            |
| 1,000                         | 20.5         | 192                 | 19.72                            |
| 1,500                         | 21.4         | 189                 | 19.58                            |

When no additional capital expenditure is required, producing ethyl vanillin can add value to the portfolio even at a level of 500 tons per annum, provided that the fixed cost/kg remains the same.

Ethyl vanillin would therefore be the preferred vanillin product as it adds more value than the equivalent amount of vanillin. However, in comparison to including OMC in the suite of products produced, ethyl vanillin still adds substantially less value.

### 12.3.3 Optimise Portfolio with Flavour Grade PAA and Technical Grade pHB

In considering the above analysis, the optimal portfolio of the large-scale chemicals is hence to produce 1,691 tons pHB; 1,719 tons pAA; 1,500 tons menthol and 2,000 tons OMC. The project return under this set of conditions is 24.8%. These capacities will be used as the basis for further analysis.

Adding capacity of the higher value forms of the pAA and PHB to the portfolio as defined can now further optimise the portfolio of products.

#### (a) pAA Flavour Grade

Table 34 depicts the impact on the portfolio of producing flavour grade pAA. The pAA flavour grade market is 550 tons per annum.

**TABLE 34: pAA Flavour Grade Capacity vs Project Return**

| PAA capacity (tpa) | Real IRR (%) | Capital (R millions) |
|--------------------|--------------|----------------------|
| 0                  | 24.8         | 247                  |
| 200*               | 24.8         | 249                  |
| 400                | 24.9         | 251                  |

\* Selected as Base Case

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It can be seen that the addition of flavour grade pAA only marginally increases the project return. However, in order to broaden the range of aroma chemicals, some flavour grade material should be produced. 200 tons represents 36% of the market.

### **(b) pHB Technical Grade**

The pHB merchant market itself is very small, only being in the region of 600 tpa. The effect of producing technical grade pHB is shown in table 35. Clearly, if pHB is sold on the merchant market, the amount of pHB converted to pAA must be reduced by the corresponding amount.

**TABLE 35: pHB Technical Grade Capacity vs Project Return**

| <b>pHB sales (tpa)</b> | <b>Real IRR (%)</b> | <b>pAA capacity (tpa)</b> | <b>Capital (R millions)</b> |
|------------------------|---------------------|---------------------------|-----------------------------|
| 0                      | 24.8                | 1,719                     | 247                         |
| 250                    | 24.3                | 1,465                     | 255                         |
| 500                    | 24.4                | 1,210                     | 259                         |

Producing technical grade pHB only makes sense at a volume of over 500 tons, and even at this level the increase in project return is marginal. As this volume is nearly the entire pHB world market, introducing technical grade pHB into the portfolio is therefore not considered further.

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### 12.3.4 Conclusion

Two optimal portfolios can therefore be defined, depending on whether new capital is required for the production of ethyl vanillin or not. These portfolios are shown in the table below.

**TABLE 36: Optimal Aroma Chemical and Personal Care Intermediate Portfolio**

|                               | <b>Optimal Portfolio</b> | <b>Alternative Portfolio*</b> |
|-------------------------------|--------------------------|-------------------------------|
| <b>Sales (tons)</b>           |                          |                               |
| Menthol                       | 1,500                    | 1,500                         |
| OMC                           | 2,000                    | 2,000                         |
| PAA technical grade           | 381                      | 18                            |
| pHB technical grade           | 0                        | 0                             |
| pAA flavour grade             | 200                      | 200                           |
| Ethyl Vanillin                | 0                        | 350                           |
| Vanillin                      | 0                        | 0                             |
| <b>Capacity (tons)</b>        |                          |                               |
| Menthol                       | 1,500                    | 1,500                         |
| OMC                           | 2,000                    | 2,000                         |
| pAA                           | 1,719                    | 1,356                         |
| pHB                           | 1,691                    | 1,691                         |
| Vanillin                      | 0                        | 0                             |
| Ethyl Vanillin                | 0                        | 350                           |
| <b>Project Statistics</b>     |                          |                               |
| Real IRR (%)                  | 24.8                     | 24.9                          |
| Capital (R Millions)          | 250                      | 243                           |
| PHB cash cost (\$/kg)         | 4.35                     | 4.35                          |
| PAA cash cost (\$/kg)         | 5.17                     | 5.13                          |
| Project Turnover (\$ million) | 46.5                     | 52.3                          |
| Project Turnover (R million)  | 325                      | 346                           |

\* Alternative scenario only if no new capital is required for ethyl vanillin

### 12.3.5 Sensitivity Analysis

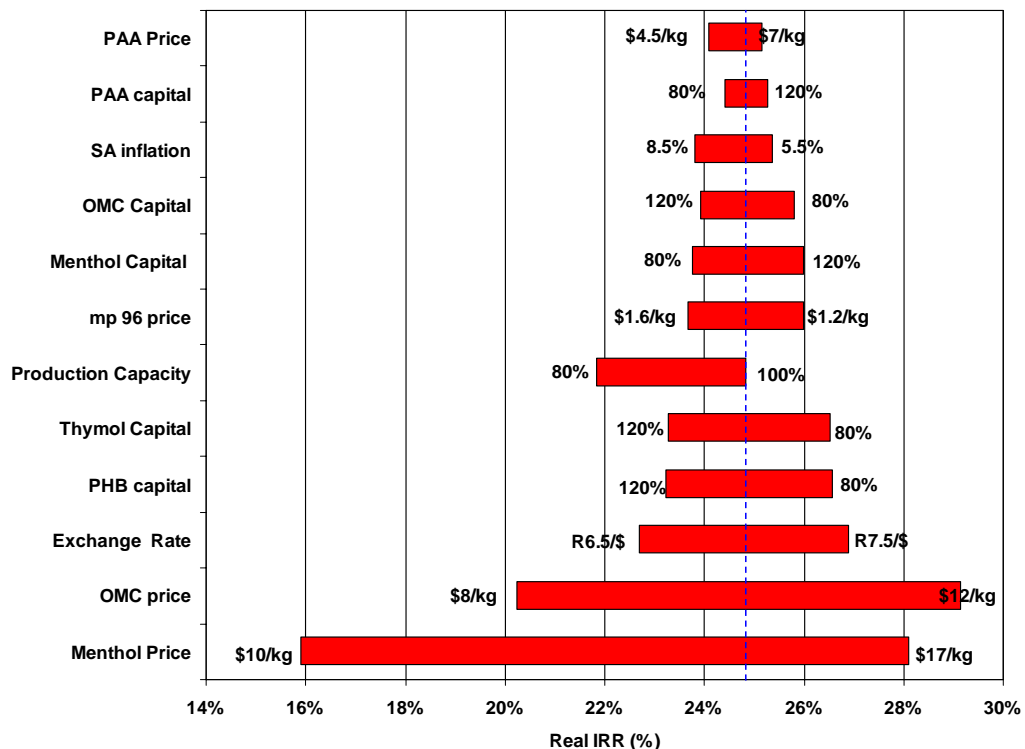
A sensitivity analysis on the key project variables was performed. The results are shown as a "Tornado Risk Diagram" in Figure 24. The tornado diagram depicts the extremes of the project IRR around the base case value, with the variables ranked according to their impact on the project IRR. The upper and lower limits depict the ranges over which the particular variable could reasonably change.

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The results show that the business is most sensitive to the menthol and OMC prices. This is not surprising, as these are the key drivers of the project. The menthol market is particularly volatile, with prices reaching as low as \$ 8.00/kg. The synthetic menthol market prices are not generally quite as volatile as the natural prices, synthetic material offering purchases some protection against this market volatility. The OMC market price is fairly stable, although prices recently have decreased due to the emergence of BASF as the market leader with a substantial production cost advantage over its competitors.

The project is also very sensitive to exchange rate. Again, this is to be expected as both selling prices and key raw materials prices such as MP96 are set in US\$. Fixed costs make up a small component of the overall cost of production. The production of thymol and pHB are the most capital-intensive processes. This is also not surprising, as these products are more bulk commodity intermediates than fine or aroma chemicals.

**Figure 24: Petrochemical Optimal Portfolio Tornado Risk Diagram**



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### **12.4 Option 2: A Bulk Intermediate Plant and an Aroma Chemical Plant**

In this option, it is proposed that the Bulk Intermediate business sell products on a committed contractual basis to the Aroma Chemical business for further conversion into the final aroma or personal care chemicals. Bulk intermediates include thymol and technical grade pAA. Technical grade pAA not sold to the Aroma Chemical plant for conversion into OMC or flavour grade pAA is sold into the merchant market at the world prices as described in section 12.1 (point 9). All products sold by the Aroma Chemical plant are at the indicated world prices.

The determination in this analysis is based on the optimal product portfolio as outlined in Table 36 above.

#### **12.4.1 Determination of Sales Prices of Bulk Intermediates to Aroma Chemical Plant**

The first step is to determine the prices, defined as the fully absorbed cost prices at which the Bulk Intermediate plant would have to sell the intermediates to a separate Aroma Chemical plant in order to obtain investment economics.

The benchmarking exercises were based on the determination of the cash cost of production, defined as:

**cash cost of production = variable cost + fixed cost + capital charge (10% of capital investment)**

In the determination of the fully absorbed cost, a capital charge of 25% was applied. The fully absorbed cost is therefore defined as:

**fully absorbed cost = variable cost + fixed cost + capital charge (10 - 25% of capital investment)**

Product sold on the merchant market was at world prices as prices outlined in 12.1 (point 9) above. The project's real IRR and fully absorbed cost for the bulk intermediates were determined at a capital charge of 25% across the same range of MP96 purchase prices, \$ 1.20 – 1.40/kg.

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TABLE 37: Fully Absorbed Cost of Production for Bulk Intermediates

| MP 96 price (\$/kg) | Capital Charge | Fully Absorbed Cost pHB (\$/kg) | Fully Absorbed Cost pAA (\$/kg) | Fully Absorbed Cost Thymol (\$/kg) | Real IRR (%) |
|---------------------|----------------|---------------------------------|---------------------------------|------------------------------------|--------------|
| 1.20                | 25%            | 4.45                            | 5.43                            | 2.91                               | -2.9         |
| 1.40                | 25%            | 4.99                            | 5.96                            | 2.91                               | -3.8         |
| 1.60                | 25%            | 5.53                            | 6.49                            | 2.91                               | -4.6         |

It can therefore be seen that the project will not meet an investment hurdle rate higher than 10%<sup>41</sup> even at a capital charge of 25% and low feedstock price for MP96 of \$ 1.20/kg.

The thymol price is independent of the MP96 price, being only dependant on the m-cresol purchase price, which in this exercise has been assumed to be \$ 1.80/kg. The thymol technology used in the assessment of this project is the CSIR thymol technology (at pilot level) based on standard technology. The proprietary aspect of the Mbuyu biotech technology lies in the bioresolution step in the menthol process.

At a MP96 purchase price greater than \$1.40/kg, the pAA fully absorbed cost is greater than the world price. The OMC benchmarking exercise determined that a world OMC producer needs to purchase pAA at a price of \$ 4.80 – 5.50/kg to be in a position to produce OMC competitively against BASF on a cash cost basis. It is only at a MP96 price of \$ 1.20/kg that the fully absorbed cost is within this range.

It was then determined whether by increasing the thymol sales price, the project could obtain investment economics. Flavour and Fragrance Grade thymol sells at \$ 8.00 – 10.00/kg. A price range of \$ 6.00/kg was therefore chosen. All other intermediates were sold to the Aroma Chemical plant at a fully absorbed cost price calculated as above using capital charges in the range 10 - 25%. The results of this analysis are shown in Table 38. The return on Aroma Chemical plant is also indicated.

<sup>41</sup> Assuming a real IRR of 10% is the absolute minimum return to obtain investment economics.

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TABLE 38: Determination of Project Return at Increased Thymol Price (\$6.00/kg)

| MP 96 price<br>Capital Charge (%)              | \$1.20/kg |      | \$ 1.40/kg |      | \$ 1.60/kg |      |
|--|-----------|------|------------|------|------------|------|
|  | 10%       | 25%  | 10% *      | 25%  | 10%        | 25%  |
| Bulk Intermediate Project IRR (%)              | 10.3      | 12.6 | 9.7        | 13.9 | 9.10       | 11.4 |
| Aroma Chemical Project IRR (%)                 | 46.4      | 43.4 | 44.4       | 41.3 | 42.3       | 39.3 |
| pHB Fully Absorbed Cost<br>Sales Price (\$/kg) | 3.81      | 4.45 | 4.35       | 4.99 | 4.88       | 5.53 |
| pAA Fully Absorbed Cost<br>Sales Price (\$/kg) | 4.64      | 5.43 | 5.17       | 6.00 | 5.70       | 6.49 |

\* Assumed as Base Case

Clearly, selling thymol to the Aroma Chemical Plant at \$ 6.00/kg has the ability to increase the project's return. At a MP96 purchase price of \$ 1.60/kg, the bulk intermediate plant cannot sell pAA to the OMC plant in the range \$ 4.80 – 5.50/kg even at a capital charge of 10%. The Bulk Intermediate plant can however purchase MP 96 at \$ 1.40/kg and sell pAA to the Aroma Chemical plant at a price within the required range, provided that a capital charge of no more than 10% is charged. At a MP96 price of \$ 1.20/kg, the capital charge can be increased up to 25% without compromising the sales price of pAA to the aroma chemical plant.

### 12.4.2 Conclusion

Selling bulk intermediates to the Aroma Chemical Plant at a calculated fully absorbed cost, including capital charges in the range of 10 – 25%, does not give project investment economics.

However, increasing the thymol sales price to \$ 6.00/kg, allows the project to achieve returns in the range 9.7 – 12.6% at MP 96 purchase prices of \$ 1.20 – 1.40/kg and selling pAA at prices between \$ 4.64 – 5.43/kg. At these prices, the Aroma Chemical plant will purchase pAA in the price range required to allow it to compete on a cash cost basis with BASF.

### 12.4.3 Sensitivity Analysis

A sensitivity analysis on the key project variables was performed. The results are shown as a "Tornado Risk Diagram" in Figure 25. The tornado diagram depicts the extremes of the project IRR around the base case value, with the variables ranked according to their impact on the project IRR. The upper and lower limits depict the ranges over which the particular variable could reasonably be expected to change.

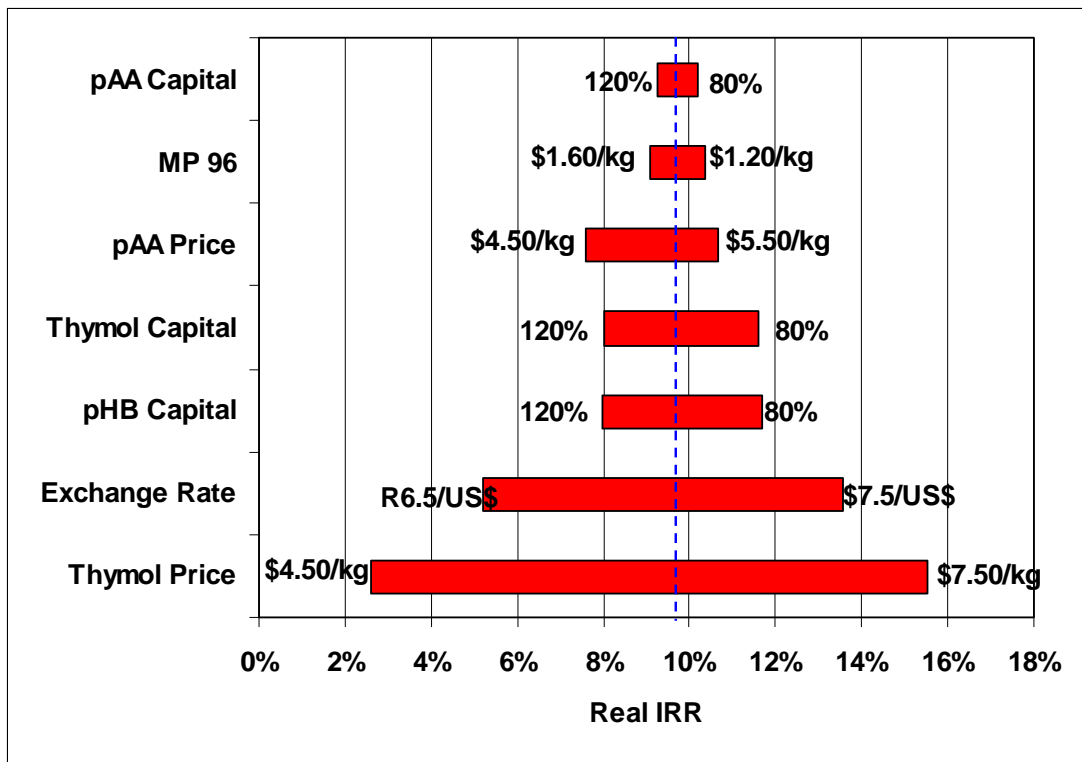
## PART 3 – AROMA CHEMICALS from PETROCHEMICAL FEEDSTOCKS

The base case scenario was assumed to be:

|                       |            |
|-----------------------|------------|
| 1. MP 96              | \$ 1.40/kg |
| 2. Capital Charge     | 10%        |
| 3. Thymol sales price | \$ 6.00/kg |
| 4. Real IRR           | 9.7%       |

As expected the Bulk Intermediate plant is very sensitive to the thymol price and the exchange rate. This is as a result of pHB and pAA having substantially lower contribution margins than thymol. As is the case with the Fully Integrated facility where menthol and OMC are the higher value-adding products, thymol is the highest value product on the Bulk Intermediate plant.

**FIGURE 25: Bulk Intermediate Plant Tornado Risk Diagram**



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### **12.5 Conclusion**

The optimal portfolio for a fully integrated aroma chemical plant has been defined. The product portfolio includes menthol and OMC but excluded vanillin. A product portfolio excluding both menthol and OMC does not meet investment hurdles. Including menthol in the portfolio increases the project's return dramatically to 19.2% at capacity of 1,500 tpa. This capacity is deemed reasonable after study of the menthol market. Including OMC to this product portfolio at a capacity of 2,000 tons increases the project's profitability even further, to a real IRR of 24.8%. The inclusion of either vanillin or ethyl vanillin detracts value from the project, and could only be considered if no new capital was required. In this instance, ethyl vanillin would be the product of choice.

The full capital investment is anticipated to be in the order of R 230 million. The CSIR obtained an estimate of the fixed capital investment required for the project was determined based on an inner battery limit for each plant. (Outer battery limit services, utilities and infrastructure would be required in addition to this investment.) The estimate is based on the cost of individual main plant equipment items, to which an installation factor has been applied in order to arrive at a total installed cost.

The factored estimate of fixed capital investment has an accuracy of  $\pm 30\%$ . The capital for technical grade pHB, technical grade pAA, fragrance grade pAA and OMC was determined in 2001 at an exchange rate of 6.25. The thymol estimate was performed in 2001 in US\$ and the menthol estimate in 2003. For the individual inner battery limit plant areas, a process development allowance factor has been determined and applied to the fixed capital investment for each. The process development allowance is a process contingency and is dependent on the status of the development of the technology.

The estimates have been corrected for inflation and are listed in the table below in January 2004 money.<sup>42</sup>

**TABLE 39: Fixed Inner Battery Limit Capital Investment - 2004 money<sup>43</sup>**

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<sup>42</sup> At exchange rate of R7.5/US\$

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| Plant                                 | Total Cost (Rm.) |
|---------------------------------------|------------------|
| Crude pHB Plant (1,691 tpa)           | 72               |
| Technical grade pAA Plant (1,719 tpa) | 18               |
| Fragrance grade pAA Plant (200 tpa)   | 2                |
| OMC (2,000 tpa)                       | 40               |
| Thymol (1,800 tpa)                    | 70               |
| Menthol Plant (1,500 tpa)             | 48               |
| <b>Total Fixed Capital Investment</b> | <b>250</b>       |

The business is most sensitive to the prices for the two key products, namely menthol and OMC. The impact of increasing the world capacity by the tonnages outlined in this report on the world prices should be considered. An entry strategy whereby the proposed capacity is installed as replacement rather than additional capacity would be favoured.

A scenario whereby a Bulk Intermediate plant supplying product to a separate Aroma Chemical plant has also been outlined. Selling the bulk intermediates to the Aroma Chemical Plant at a calculated fully absorbed cost, with capital charges in the range of 10 – 25%, does not give project investment economics. The scenario under which a Bulk Intermediate plant would be economically viable is if it sells thymol at higher than fully absorbed cost, considered in this report to be \$ 6.50/kg. MP96 purchase prices must be in the range of \$ 1.20 – 1.40/kg for the project to achieve returns in the range 10.3 – 12.6%. At these prices, the Aroma Chemical plant will also have investment economics, but more importantly the Aroma Chemical plant will be in a position to purchase pAA in the price range required to allow it to competitively produce OMC and compete on a cash cost basis with BASF.

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<sup>43</sup> The capital investments are based on the CSIR estimates performed, escalated into 2004 money. The menthol capital estimate was performed on a 1,500 tpa plant.