PART 3 – AROMA CHEMICALS from PETROCHEMICAL FEEDSTOCKS

5 BENCHMARKING ANALYSIS

5.1 The CSIR pHB-pAA Technology

During 2000 and 2002 AECI undertook a number of competitor analyses to benchmark the pHB-pAA technology developed against various producers of pAA and aroma chemicals. This was done within an Aroma and Fine Chemicals strategic framework where a basket of products derived from the intermediates, pHB, pAA and m-cresol, were targeted for commercialisation. The main conclusion reached from these studies was that AECI would be able to be world competitive in aroma chemicals, providing OMC and menthol were the main pull through products for the pAA and m-cresol intermediates, should the complex based on this new technology. A basket of smaller volume aroma products would benefit from the economy of scale of an integrated aroma chemicals complex.

All commercial pAA technologies are based on a two-step process route involving oxidation and methylation of the starting raw material p-cresol. The routes differ in the sequence in which the oxidation or methylation step takes place, and the nature of the chemistry employed for each step. All commercial processes require a relatively pure source of p-cresol as raw material feedstock. The novelty of the CSIR developed technology resides in the selective oxidation of p-cresol to pHB from a feedstock consisting of mixture of p- and m-cresol. A pure stream of by-product m-cresol can be recovered for sale, or subsequent conversion to other useful aroma or fine chemicals. Historically mixed m-cresol, p-cresol (MP) feedstocks have been cheaper than p-cresol.

5.1.1 Methodology of Competitiveness Analysis

The general methodology adopted for carrying out the competitive analysis was to benchmark the cash cost of production of a producer using the technology concerned with that of the world cost leader of the specific product. For the purpose of the analysis, cash cost of production was defined as the sum of the variable and fixed costs, nett of any by-product credits. Where multiple sequential process plants were required to produce the product through a series of intermediate products, these intermediates were transferred at their respective cash cost of production. The processes were benchmarked on an international basis in US$.

Variable costs were determined from unit usages of all raw materials (including the intermediates), utilities and services that could be reasonably estimated for the process, and the corresponding transfer or commercial input prices. Because the Inside Battery Limits plant approach was adopted, all utilities and services were assumed to be purchased at battery limits. These input prices were based on that determined by AECI in 2001 for its Richards Bay site. The fixed costs included depreciation. The fixed costs elements were calculated as follows:

- Maintenance material (1): 2.0% of inner battery limit capital cost
- Maintenance labour (2): 2.0% of inner battery limit capital cost
- Manpower (3): 7.5% of inner battery limit capital cost
- Site & General Overhead: 1.2% of inner battery limit capital cost (= 10% of 1+2+3)
- Depreciation: 10% of inner battery limit capital (straight line)
- Selling & Admin Costs: 0.5% of sales

The inner battery limit capital costs of the different process plants had been determined by Ardeer Engineering (Pty) Ltd at various stages of their development either commissioned by AECI or the CSIR.

Where detailed information of a competitor's processes were not obtained through competitor intelligence networks that had been set up by AECI, techno-economic modelling of the process had been done based on open literature and patent information.

The objective of this benchmarking exercise is to assess the competitiveness of a producer investing in a plant in South Africa employing the pHB-pAA technology developed by the CSIR and supplying pAA and naturally arising m-cresol into the world markets for these products. Two issues with respect to the competitiveness of the technology have been assessed:

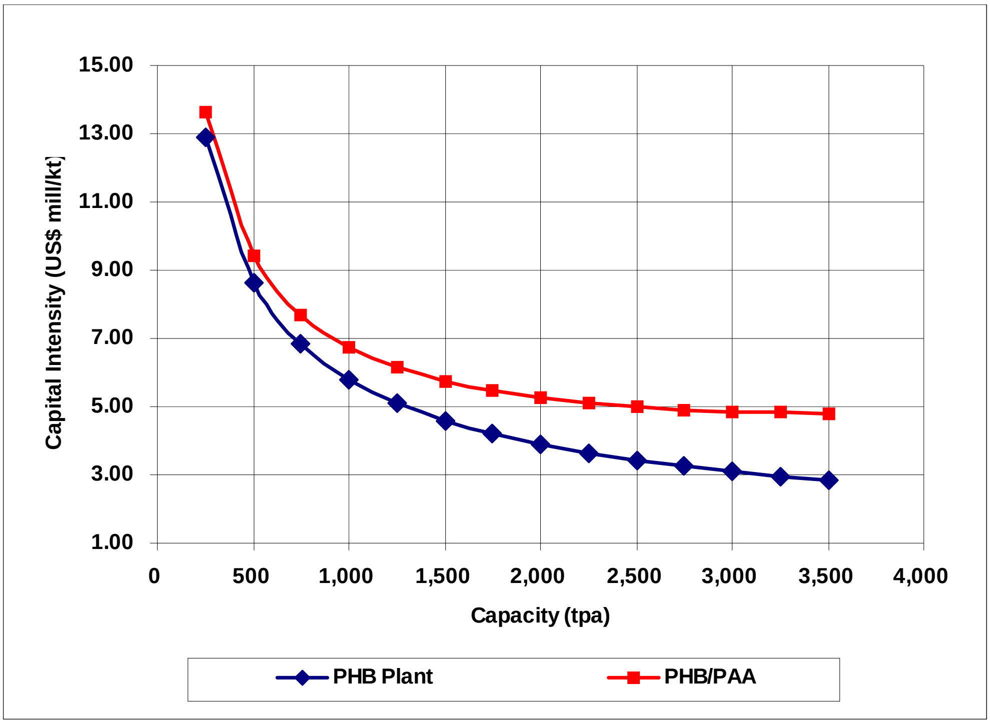
- The economy of scale of a plant based on the new pHB-pAA technology
- The competitiveness of a South African based pAA producer opposite the lead world pAA producer

5.1.2 The Economy of Scale of the pHB-pAA Technology

The economy of scale of a production plant indicates how the capital investment per unit of production relates to the plant capacity and shows at what capacity the effectiveness of capital invested would reach a minimum. This is important as it determines whether the technology, irrespective of its competitiveness, will result in an investment case at the plant capacity contemplated. This relationship for the pHB-pAA technology developed by the CSIR is shown in figure 9.

The chart shows that the capital cost per unit capacity plateaus to around $5/kg pAA at about 2,500 tpa. No substantial further capital cost benefit will be derived for a plant exceeding this capacity. Conversely, any plant built that has a smaller capacity will not benefit from the economy of scale and might not yield investment economics.

FIGURE 9: Economy of Scale of CSIR pHB-pAA technology



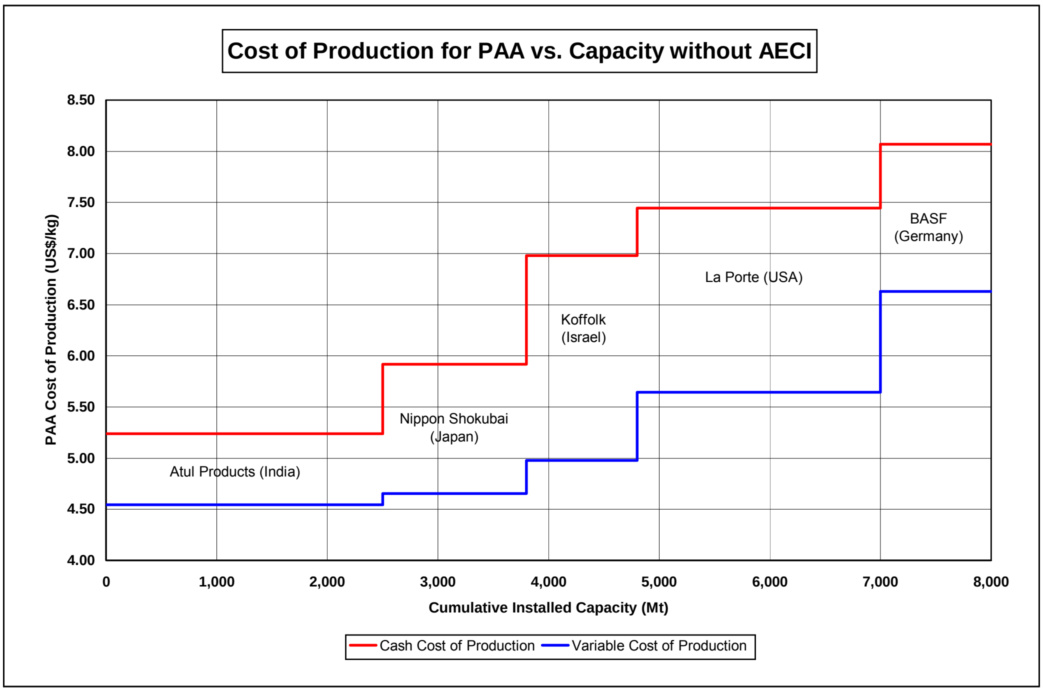
5.1.3 Competitive Analysis of pAA Producers

During the 1990's the main producers of pAA were Atul, Nippon Shokubai, BASF, Laporte (Degussa) and Koffolk. All these producers use/d processes based on p-cresol, only Atul and LaPorte have a captive supply from dedicated plants converting toluene to p-cresol. Nippon Shokubai, BASF and Koffolk buy p-cresol on the merchant market. In 2002, AECI carried out a competitive analysis of these producers based on the cash cost of production of pAA (variable plus fixed costs). Techno-economic data were obtained from reliable AECI business intelligence networks.

Long-term predicted average raw material prices formed the basis for the input costs for the analysis. With a p-cresol input price of US$ 2.40/kg assumed for all producers, the Cash Cost of Production for existing and dormant producers was determined, and is shown in figure 10, ranked from lowest to highest cost producer.

The high-cost producers LaPorte and Koffolk, were not deemed to be competitive at the prevailing pAA prices levels of less than $6.50/kg, and the chart predicted that these producers would exit the pAA business, given the sizeable capacity overhang compared to demand (2000 demand for pAA was 4,500 tonnes per annum). This indeed occurred with LaPorte exiting in 1999 and Koffolk in 2000.

FIGURE 10: PAA Cost of Production Analysis



BASF was also not competitive at those prices for technical grade pAA, and chose to focus on the upper-end fragrance grade market. Its non-competitiveness in technical grade pAA may have been the reason why BASF forward-integrated into OMC production in 1995. Although BASF is no longer a major producer of technical grade pAA, its fragrance grade pAA, derived from its electrochemical oxidation process, is considered to be the industry standard.

The second lowest cost producer, Nippon Shokubai, has a single dedicated pAA plant in Japan, which uses p-cresol as a feedstock. The p-cresol is purchased from the world market.

Atul's pAA Production Costs

The lowest cost producer, Atul has two dedicated single-product pAA plants, both of which use pure p-cresol as a feedstock. Atul produces p-cresol in two plants using toluene as feedstock. Two-thirds of the p-cresol produced by Atul is consumed in the production of pAA, with the remainder being used for captive production of p-cresidine and Butylated Hydroxy Toluene, or sold into the local Indian market. pAA is thus the main driver for p-cresol production at Atul.

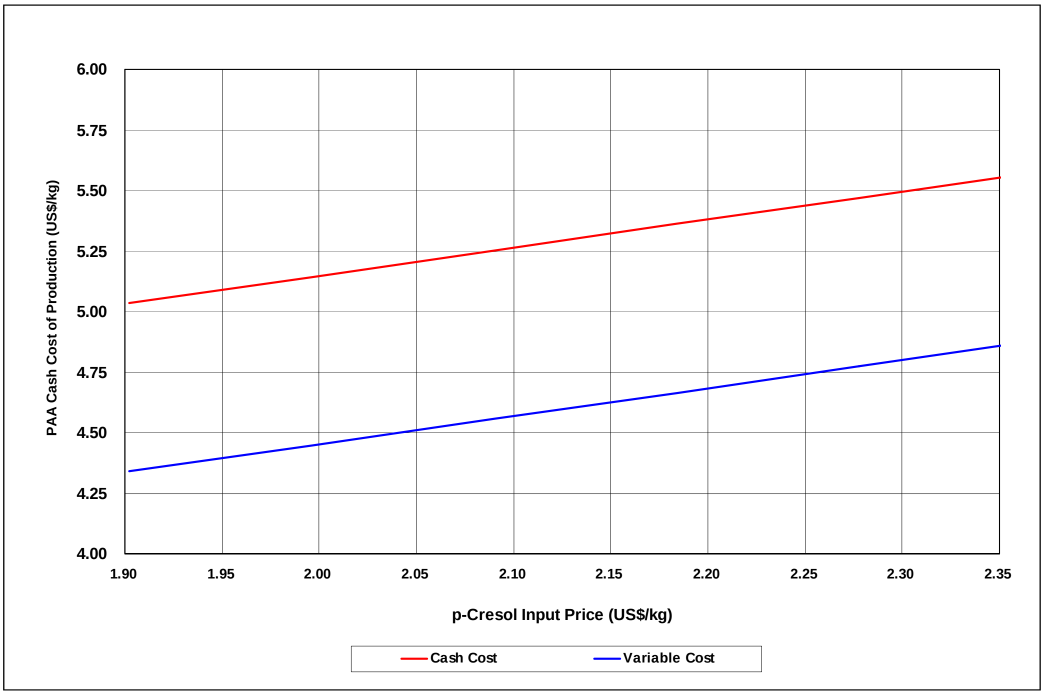
Atul's cash cost of production for pAA is therefore directly linked to the price of toluene as the raw material for its p-cresol production. Toluene is a commodity chemical and its price is linked directly to the commodity cycle. The following chart shows the effect of the toluene price on Atul's variable and cash costs of production for p-cresol used in the production of pAA for export.

FIGURE 11: Atul Cost of Production for p-Cresol

The lowest and highest prices for toluene over a five-year period leading up to 2001 had been $160/ton and $ 380/ton respectively. For Atul, this equates to minimum and maximum cash costs of production for p-cresol of $1.91/kg and $2.33/kg respectively. Over this same period the low and high prices for merchant p-cresol had been $2.20/kg and $2.80 respectively. The figure below shows the equivalent cost of production for pAA for this range of p-cresol prices, assuming p-cresol is transferred at cash cost.

Based on the above assumptions, Atul's cash cost of production of pAA is estimated to range between a minimum of $ 5.05/kg and a maximum of $5.54/kg. Variable costs account for 84% of the total cash cost.

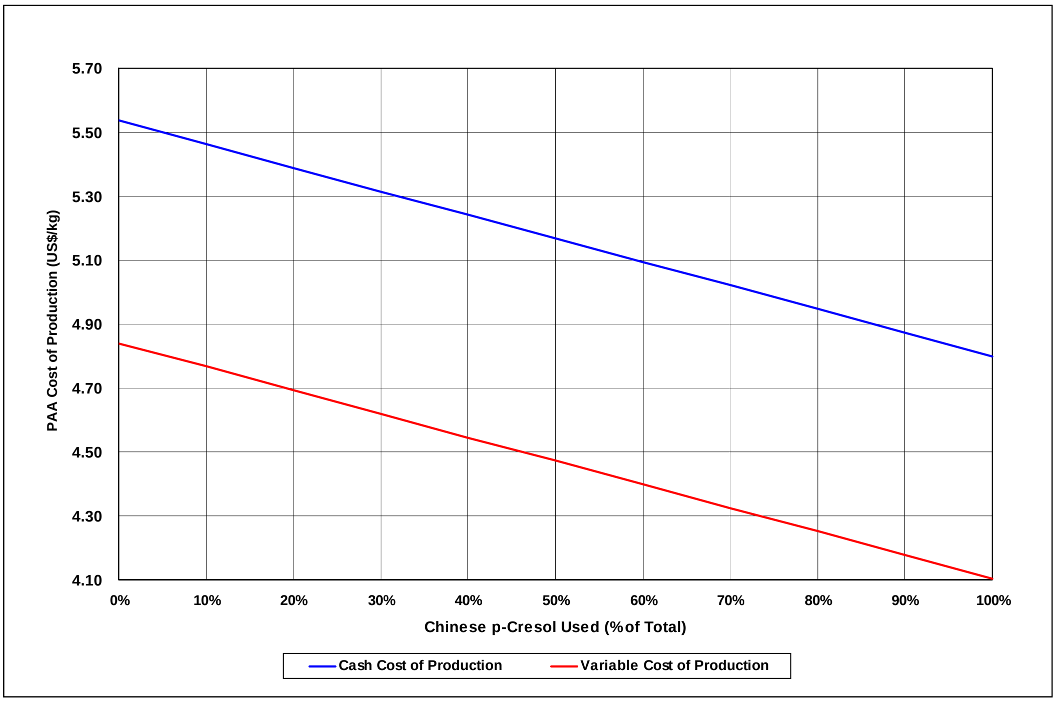
FIGURE 12: Atul Cash Cost of Production for pAA



The entry of BASF into the OMC world market in 1995 with a non-pAA based technology, placed significant cost pressure on pAA-based OMC producers to compete. With OMC being the major sink for pAA, this pressure also cascaded down to Atul. Against a rising cost of purchased toluene, a likely option Atul could pursue to reduce production costs of pAA further is to substitute some of its captive p-cresol supply with cheaper Chinese p-cresol at $ 1.70/kg. The effect on Atul's cash cost of production of pAA of going down this route, is shown in figure 13.

The chart shows that, without taking into account the cost penalty associated with a turned down p-cresol plant, Atul could theoretically reduce its cash cost of production of pAA further from a previous minimum of $5.05/kg to $4.80/kg at 100% substitution with Chinese p-cresol. Without having further intelligence work, it is uncertain how Atul has been managing the price pressure on the supply of pAA.

FIGURE 13: Atul Cost of Production for pAA - Effect of Using Chinese p-Cresol



5.1.4 The Competitiveness of pAA Production in South Africa

A South African pAA producer based on the CSIR developed pHB-pAA technology would have the flexibility of starting with a feedstock of varying compositions of p-cresol and m-cresol. This could range from pure p-cresol to a mixture consisting of 40% p-cresol and 60% m-cresol, such as the MP99 supplied by Mitsui or Sumika-Merichem. The South African producer's production cost of pAA would therefore depend on the composition of the feedstock selected. Despite this raw material flexibility, from a reaction chemistry perspective, the ideal composition is a mixture consisting of 50% p-cresol and 50% m-cresol, as would be the case with Merisol's MP99 and MP96 cresol products.

The competitiveness of a potential South African based pAA producer was benchmarked against Atul based on two feedstock scenarios:

- Pure p-cresol
- MP96, consisting of roughly 47% p-cresol and 49% m-cresol

Pure p-Cresol Feedstock

Atul's cash cost of production of pAA compared with that of a South African producer starting from merchant p-cresol, is shown in table 20. The input p-cresol price for the South African producer corresponds to the high and low prices of world merchant p-cresol of $2.80/kg and $2.20/kg respectively over the five-year period prior to 2001. Atul's input p-cresol price was based on transferring p-cresol at its cash cost of production of p-cresol.

TABLE 20: Comparison of Atul and CSIR Cash Costs of Production

	Atul		**CSIR Technology**	
	Toluene Price ($/kg)	**Cash Cost of pAA ($/kg)**	**p-Cresol Price ($/kg)**	**Cash Cost of pAA ($/kg)**
High	$ 0.38/kg	$ 5.54/kg	$ 2.80/kg	$ 6.07/kg
Low	$ 0.16/kg	$ 5.04/kg	$ 2.20/kg	$ 5.49/kg

Comparing the cash costs of production of pAA for the two producers on the basis of the high and low input prices of feedstock these two producers would experience, the South African producer would not be competitive opposite Atul. Atul's lower cash cost of production results from the lower price of p-cresol transferred at cash cost, compared with that of merchant p-cresol, of which the price is set by Butylated Hydroxy Toluene market dynamics, the main sink for p-cresol, and not by the toluene commodity feedstock price variation world p-cresol producers would have to contend with.

Should the playing fields be level, in that both Atul and the SA producer purchased Chinese p-cresol, then the South Afircan pAA producer would still not be able to compete with Atul on a cash cost basis as shown in table 21.

TABLE 21: Comparison of Atul and CSIR Cash Cost of Production Using Chinese p-Cresol

		Atul	**CSIR Technology**
	Chinese p-Cresol ($/kg)	**Cash Cost of pAA** ($/kg)	**Cash Cost of pAA** ($/kg)
High	$1.90/kg	$5.04/kg	$ 5.21kg
Low	$1.70/kg	$4.80kg	$ 5.01/kg

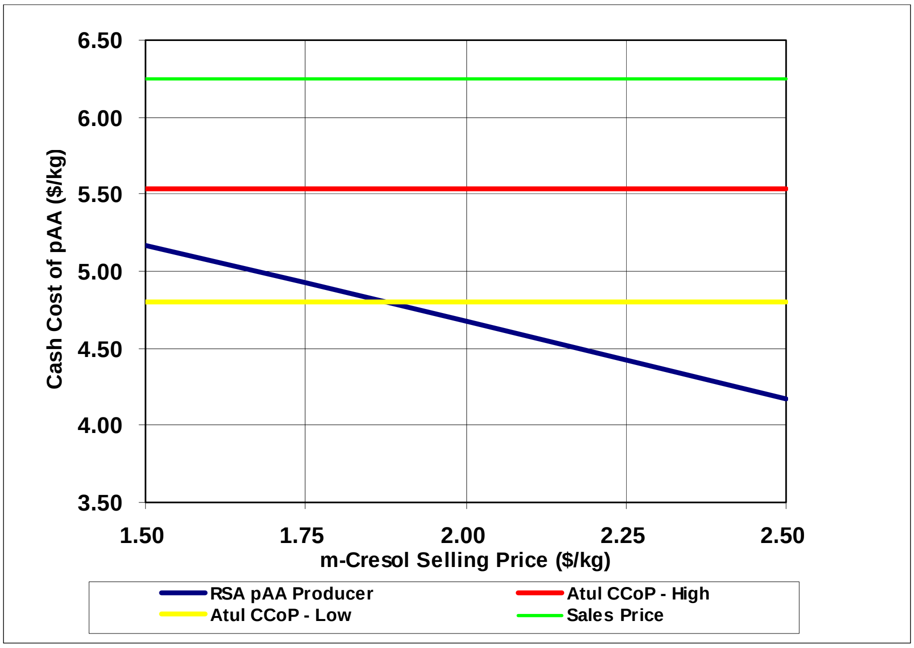
This analysis indicates that the cost competitiveness of the CSIR developed pHB-pAA technology does not lie in its p-cresol conversion reaction chemistry (yields and reaction rates), but in its ability to selectively convert a cheaper mixed para and meta cresol feedstock that also yields a value added by-product, and that other pAA producers cannot use as starting material.

Merisol MP96 Cresol Feedstock

At the time of the AECI Study, it was proposed by Merisol that an appropriate feedstock for the pHB-pAA technology would be M96, a mixed cresol feedstock of 96% purity and consisting of 47% p-cresol and 49% m-cresol. In 2001, Merisol indicated a price of $1.40/kg for this feedstock. The cash cost of production of a South African pAA producer sourcing MP96 at $1.40/kg and selling cresol at different price levels, is shown in figure 14.

The chart shows that a South African pAA producer at economy of scale production of 2,500 tpa, supplied with MP96 would be competitive against Atul, and to maintain a competitive position, it would be necessary that the m-cresol selling price should not fall below $1.80/kg.

FIGURE 14: Cash Cost of Production – South African pAA producer vs Atul



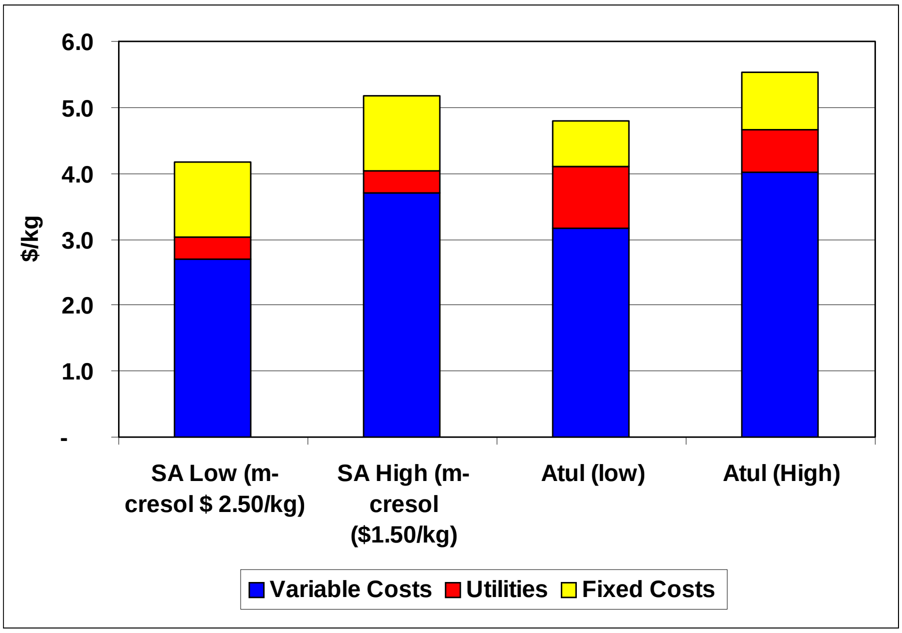
The South African pAA production costs are tabulated below at $ 1.40/kg MP96 and selling m-cresol at $ 1.80/kg.

TABLE 22: South African pAA Cash Cost of Production

	$/kg	**%**
Net Cresols	1.90	39
Caustic Flake	0.63	13
Methyl Chloride	0.35	7
Other Raw Material Costs	0.52	18
Total Raw Material Costs	3.39	70
Utility Costs	0.35	7
Fixed Costs	1.14	23
Total Cash Cost of Production	**4.87**	**100**

Figure 15 demonstrates the breakdown comparison of the South African producer's costs *vs* Atul's cost for their respective high and low cash cost of production.

FIGURE 15: Comparison of Atul and SA pAA Production Costs



This graph clearly demonstrates that the South African producer's cost advantage is as a result of the technology using the mixed cresol and hence generating m-cresol as a natural arising, provided that this m-cresol can be sold at a price over $ 1.80/kg.

5.1.5 Key Issues and Conclusions

The competitiveness of a South African pAA producer employing the CSIR pHB-pAA technology has been benchmarked against Atul by analysing their respective cash costs of production (defined as the sum of the variable and fixed costs associated with producing pAA). Such a producer would not be competitive should it base its operation on pure p-cresol sourced on the world market. The producer would however, be able to compete and retain its competitive position should it source MP96 at the benchmark purchase price of $1.40/kg indicated in 2001, and sell the naturally arising by-product m-cresol at prices greater than $1.80/kg. The question as to whether the facility would have investment economics will be answered in the techno-economic study.

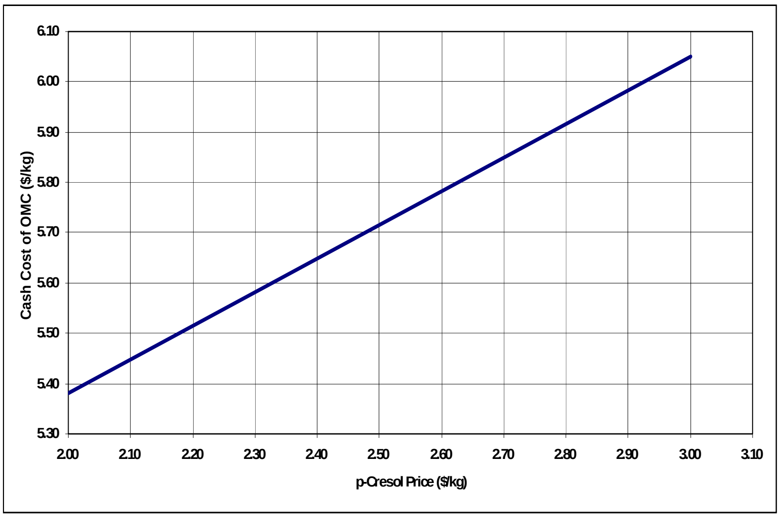
5.2 The Competitiveness of OMC Production in South Africa

The competitiveness of a South African based OMC producer supplied from a captive source of pAA from an integrated facility opposite the lead world OMC producer will be analysed.

The non-pAA technology used by BASF to produce OMC also starts with p-cresol as raw material. BASF does not have a captive source of p-cresol, it therefore purchases its feedstock on the world merchant market. The cash cost of production of OMC at BASF hence varies with the movements in price of world merchant p-cresol. The cash cost of production for OMC at BASF as a function of its p-cresol input price is shown in figure 16 over the same range of highs and lows previously discussed.

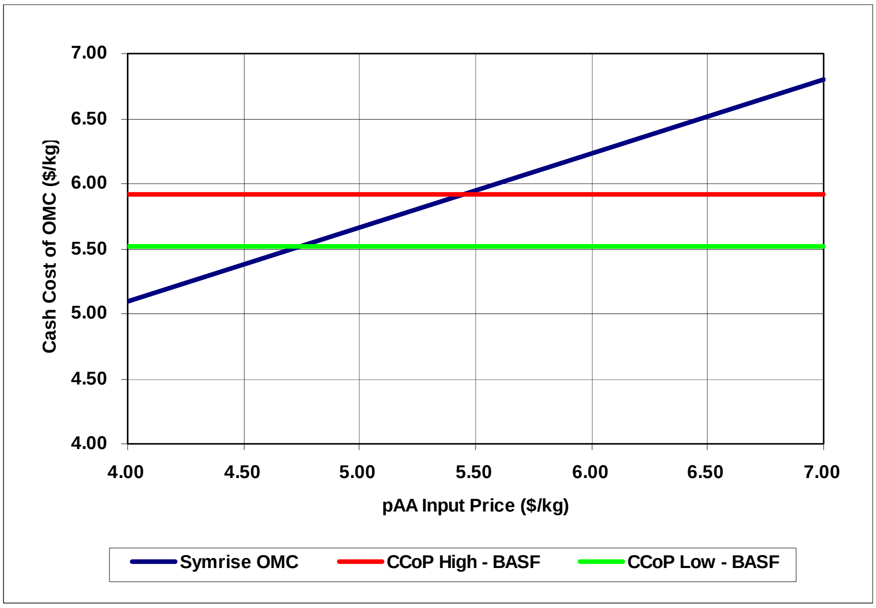
At the upper p-cresol price of $2.80/kg, BASF's cash cost of production for OMC is $ 5.92/kg, and at the lower price of $ 2.20/kg, $ 5.52/kg.

FIGURE 16: BASF Cash Cost of Production for OMC



For Symrise, the second lead producer of OMC, to compete with BASF at these cash costs of production for OMC, it would need to purchase pAA at input prices of $ 5.45/kg and $4.74/kg, corresponding to BASF's high and low cash costs for OMC, as shown in figure 17 below.

FIGURE 17: Symrise Cash Cost of Production



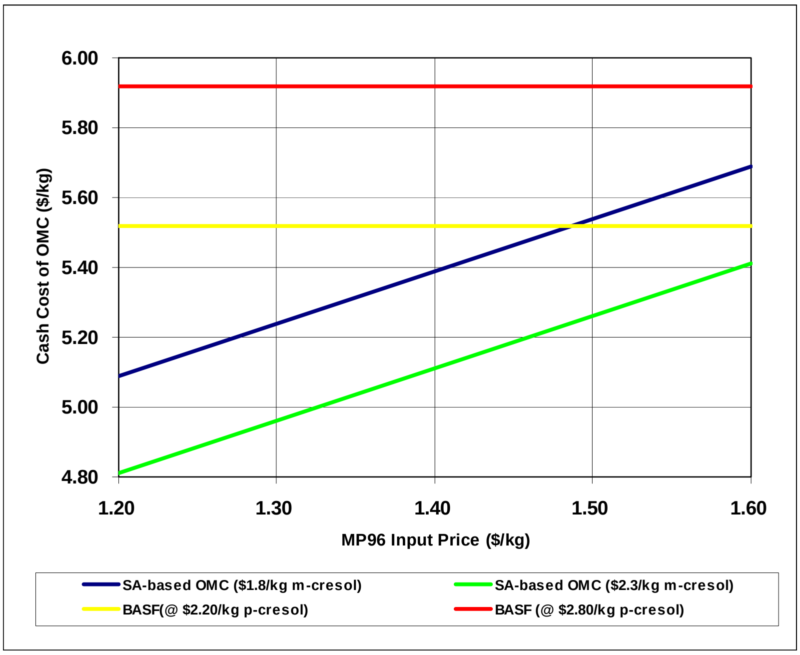
These are extremely low selling prices for pAA and it is doubtful whether there are any pAA producers that will be able to match these price demands.

The competitiveness of producing OMC in South Africa from a facility with integrated pAA and OMC plants were benchmarked against BASF. In line with the assessment framework followed for pAA, the facility would produce only OMC and the naturally arising m-cresol by-product. Competitive enhancement through producing additional aroma or fine chemical intermediates has been ignored, but will be assessed through the techno-economic model evaluation later.

The OMC cash cost for such a facility has been estimated and the results are shown in figure 18. The chart shows the cash cost for a South African producer at input prices for MP96 varying between $1,20/kg and $1.60/kg at two levels of m-cresol prices, $1.80/kg and $2.30/kg. Included in the chart are the high and low cash cost for OMC production at BASF.

The outcome of this analysis is that a South African OMC producer with a captive source of pAA from a dedicated pAA plant will be able to compete on a cash cost basis with BASF over the MP96 price range $1.20 – 1.50/kg selling m-cresol at $ 1.80/kg. The question as to whether the facility would have investment economics will be answered in the techno-economic study.

FIGURE 18: Cash Cost of Production of pAA-based OMC in South Africa



BASF’s cash cost of production at the two indicated p-cresol prices is outlined below.

TABLE 23: BASF OMC Cash Cost of Production

	p-Cresol ($2/20/kg)	**p-Cresol ($2.80/kg)**
p-Cresol	1.46	1.86
Other raw materials	1.61	1.61
Utilities	1.13	1.13
Total Variable Cost	**4.20**	**4.60**
Fixed Costs	1.32	1.32
Total Cash Cost of Production	**5.52**	**5.92**

Fixed and utility costs therefore account for between 41 and 44% of the BASF cost of production. Hence, as was the case with the Rhodia European vanillin business, the strengthening of the Euro will have had a major impact on the profitability of BASF's business.

5.2.1 Key Issues and Conclusions

A far greater stumbling block than competitiveness of the technology against Atul, is the pAA prices now required by a pAA-based OMC producer to compete with BASF on a cash cost basis. These estimated prices are in the range of $4.80 - 5.50/kg, and are extremely low compared to market pAA prices of $6.00 - 6.50/kg prevailing during 2001. It is doubtful whether these pAA prices could be matched on a plant based on any of the current practiced or developed pAA technologies. A new supplier of pAA into the international market will have to supply the largest portion of its capacity into the OMC market sector. In order to persuade current purchasers of pAA to switch suppliers, it is highly likely that the supplier will have to reduce its pAA price into the range at which the OMC producer can compete against BASF on a cash cost basis. At these prices, the South African producer will have very little margin remaining to reward the capital investment.

A South African producer of OMC back integrated to a pAA plant using the CSIR developed technology would however, be competitive against BASF on a cash cost basis, providing it can source a MP96 type feedstock at the purchase prices indicated by Merisol in 2001, and can obtain a m-cresol credit corresponding to prices exceeding $1.80/kg. The economy of scale analysis of the CSIR pHB-pAA technology would suggest that for the facility to be based on robust economics, the pAA plant would have to have a capacity exceeding around about 2000 tpa.

5.3 The Competitiveness of Vanillin Production in South Africa

The competitiveness of a producer investing in a plant in South Africa employing the pHB-vanillin technology developed by the CSIR and supplying naturally arising m-cresol into the world markets for this product has been assessed. Because the world market for ethyl vanillin is only 2,000 tpa compared to vanillin which is 10,500 tpa, ethyl vanillin is unlikely to be a major pull through product justifying the implementation of a large scale pHB plant. It has been shown above that a pHB front-end plant would have to have a capacity exceeding 1,500 tpa for the investment to benefit from economy of scale. Ethyl vanillin has therefore not been benchmarked. The following aspects of vanillin's competitiveness have been assessed:

- The economy of scale of a plant based on the new pHB-vanillin and ethyl vanillin technology.
- The competitiveness of a South African based Vanillin producer opposite the lead world producer.

5.3.1 The CSIR developed Vanillin/Ethyl Vanillin Technology

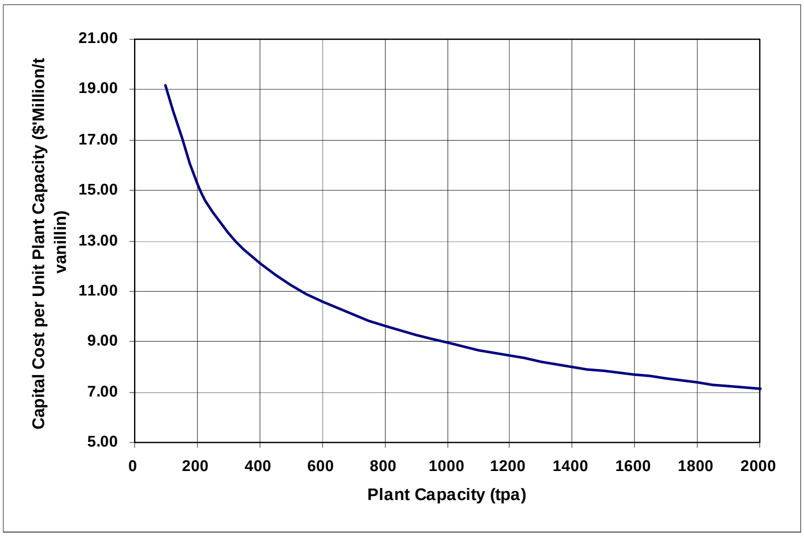
The CSIR vanillin/ethyl vanillin technology has been modified from its original version since the CSIR took over the technology from AECI. The new process route is based on brominating pHB to bromo-pHB (the same for vanillin and ethyl vanillin), then converting the bromo-pHB to either the sodium salt of vanillin (*via* methoxylation) or the sodium salt of ethyl vanillin (*via* ethoxylation) *via* a displacement reaction. After the respective displacement reactions, which follow different process steps for the two products, pure crystalline products are obtained through the same subsequent process steps of acidification, distillation and crystallisation of vanillin/ethyl vanillin.

The economy of scale of either a vanillin or ethyl vanillin plant has been determined based on a capital cost estimate of a 500 tpa ethyl vanillin plant carried out for the CSIR by Ardeer Engineering (Pty) Ltd. For this analysis, the capital cost was amended to exclude utilities.

Because the physical plants for stand-alone production of vanillin or ethyl vanillin are almost identical (except for the displacement step), the capital costs for the two products have been assumed to be of the same order of magnitude.

Figure 19 shows the economy of scale in terms of the capital cost investment per unit plant capacity for a range of plant capacities. This figure indicates that for both vanillin or ethyl vanillin stand - alone plants, a capacity of less than 1,000 tpa would not be a cost effective investment. The western producers of vanillin, Rhodia and Borregaard, have plants of vanillin capacities exceeding 2,500 tpa. Three of the leading Chinese producers all have plants with capacities of at least 1,000 tpa.

FIGURE 19: Economy of Scale for a South African pHB-based Vanillin Producer



5.3.2 The Rhodia Vanillin Technology

Rhodia, the cost leader, produces vanillin based on a technology involving the catechol / guaiacol process route. This route to vanillin is complex, comprising four process steps, and involves a number of flammable, toxic and carcinogenic solvents.

The AECI intelligence of the Rhodia production costs has not been as extensive as that gathered by AECI from its networks on pAA, OMC and menthol competitors. Most of the perspectives presented in this paper therefore were developed through techno-economic modelling of the process chemistry of the catechol / guaiacol route.

Rhodia has a captive supply of the raw material, catechol. It arises as an intermediate on dedicated phenol hydroxylation plants in Rhodia’s plants in the USA and Europe, and is co-produced with hydroquinone in a fixed ratio of about 3t of catechol to 2t of hydroquinone. This ratio is constrained by the process chemistry. Rhodia’s cash cost of production of vanillin is thus primarily driven by the input price of phenol, which follows the global phenol commodity cycle. From a process chemistry model of the phenol hydroxylation process, Rhodia’s cash cost of production of catechol has been estimated to range between $ 2.73/kg and $ 3.11/kg for input prices of phenol ranging between $ 0.60/kg and $ 1.00/kg.

Over this range of input catechol prices, the cash cost of production of vanillin was estimated, and the results are shown in figure 20. Credit for the by-product sodium sulphate has been excluded in the calculation so that a direct comparison can be made with the CSIR vanillin technology where it has also been ignored due to non-definition of a sodium sulphate recovery scheme.

FIGURE 20: Cash Cost of Production of Vanillin at Rhodia

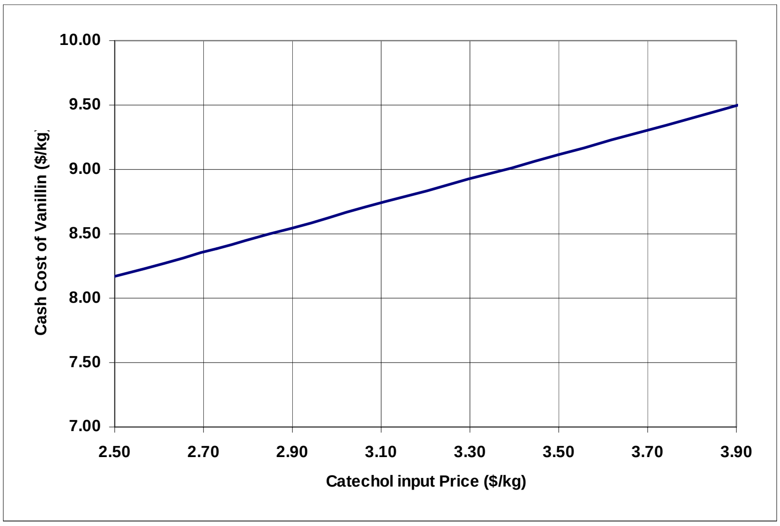


Figure 20 shows that at a maximum calculated input cash cost price for catechol of \$3.11/kg, Rhodia would have a cash cost of production for vanillin below \$ 9.00/kg.

The exercise was performed in US\$ as the Vanillin business is conducted in this currency. In addition, the larger of the two Rhodia plants is in the USA. 38 – 40% of the Rhodia US\$-based cash cost of production are fixed and utilities costs, the other input costs being raw materials which are priced in US\$. The US cash cost of production was calculated to be in the range of \$ 8.39 – 8.75/kg. The rhodia cash cost of production is outlined in more detail below.

TABLE 24: Rhodia US based Cash Cost of Production for Vanillin (Phenol US\$ 0.60/kg)

	\$/kg	**% of Cash Cost of Production**
Phenol	0.54	6.5
Dimethyl Sulphate	1.17	14
Glyoxylic Acid	1.43	17
Other Raw Materials	1.91	23
Utilities	1.04	12
Total Variable Costs	**6.09**	**72.5**
Total Fixed costs	**2.30**	**27.5**
TOTAL CASH COST of PRODUCTION	**8.39**	**100**

The fixed cost of production includes an amortisation and financial charge. This cost would relate to the age of the plant and equipment, although Rhodia's plants are most likely to be fully depreciated.

The Euro has strengthened by 42% between 2001 and 2004. The US\$/Euro exchange rate will therefore have an effect on the cash cost of production of the European Rhodia plant. In Europe, at current exchange rates and taking into account the contribution of fixed and utility costs, the European cash cost of production is more likely to be in the region of \$ 9.28 – 9.64/kg, translating into an 11% increase over the US cash cost of production. The strengthening of the Euro will have therefore had a major impact on the profitability of the Rhodia European vanillin business. At a selling price of US \$ 12.00/kg, the European Rhodia gross margin will have decreased from an average of 29% to 21% during this period.

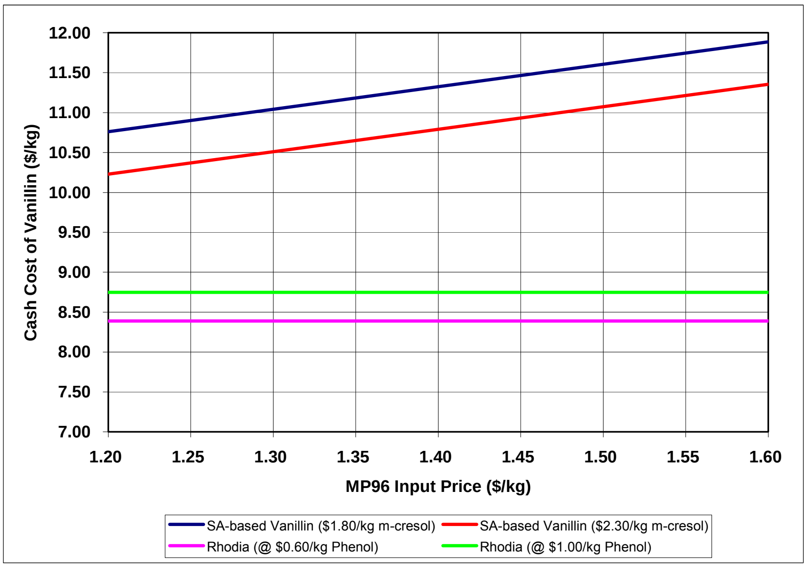
5.3.3 Competitive Analysis

The competitive analysis is based on the latest CSIR vanillin technology which has been benchmarked only against the cost leader, Rhodia. A number of assumptions have been made:

- The vanillin plant is back integrated to a dedicated pHB plant based on the novel CSIR selective p-cresol oxidation process.
- The pHB front-end plant is supplied with an MP96 type feedstock of which the m-cresol to p-cresol ratio is substantially 1 to 1.
- The pHB is transferred to the vanillin plant at cash cost.
- The naturally arising m-cresol can be sold at market prices ranging between $ 1.80/kg and $ 2.30/kg.

The cash cost of production competitiveness of a South African pHB-based vanillin facility compared with that of Rhodia is shown in figure 21. The figure shows that a South African producer would not be able to compete on cash cost basis with Rhodia for any of the MP96 input prices and m-cresol selling prices considered. The low and high cash costs of $ 10.23/kg and $ 11.89/kg for South African based vanillin production substantially exceeds those achievable by Rhodia. With global commercial prices of vanillin being within the $ 9.00 - $ 12.00/kg expectation band, this would leave little margin for a South African producer to reward capital investment.

FIGURE 21: Cash Cost of Production of pHB-based Vanillin in South Africa



Clearly, selling m-cresol at $ 2.30/kg gives the best South Africa cash cost of production. Table 25 below outlines the full cost of production for vanillin using purchased MP 96 at $1.20/kg and selling m-cresol at $ 2.30/kg.

Further analysis of the South African cash cost of production determines that fixed costs constitute 33 % of this cost, the fixed cost including a capital charge.[25] From this table it can be seen that on a pure variable cost basis, the CSIR process is 12.5% more expensive than the Rhodia cash cost of production outlined above.

TABLE 25: South African Vanillin Cash Cost of Production

	$/kg	**% of Cash Cost of Production**
Selling Price	12.00	
Net Cresols	0.92	9
Caustic Flake	0.67	6.5
Ethyl Acetate	1.02	10
Sodium	1.73	17
Bromine	0.87	8.5
Other Raw Materials	0.98	9.5
Utilities	0.66	6.5
TOTAL VARIABLE COSTS	**6.85**	**67**
Labour	1.12	11
Other Fixed Costs	0.78	7.5
TOTAL FIXED COSTS	**1.89**	**18.5**
TOTAL COST OF PRODUCTION	**8.74**	**85.5**
Capital Charge	1.49	14.5
TOTAL CASH COST of PRODUCTION	**10.23**	**100**
Contribution to Profit	**1.77**	

Hence, the integrated pHB process, using a mixed cresol feedstock, which allows the sale of m-cresol, does not impart any competitive advantage in the production of vanillin when compared to the Rhodia process. The South African cost of production, if the amortisation or finance charge is excluded, is however only 4% more expensive than the US Rhodia cash cost of production. The Rhodia fixed cost including depreciation is $2.30/kg *vs* the SA $3.39/kg, due to the fact that the Rhodia plants are likely to be fully depreciated. A South African producer is therefore closest to the Rhodia's cash cost of production if finance charges are not accounted for.

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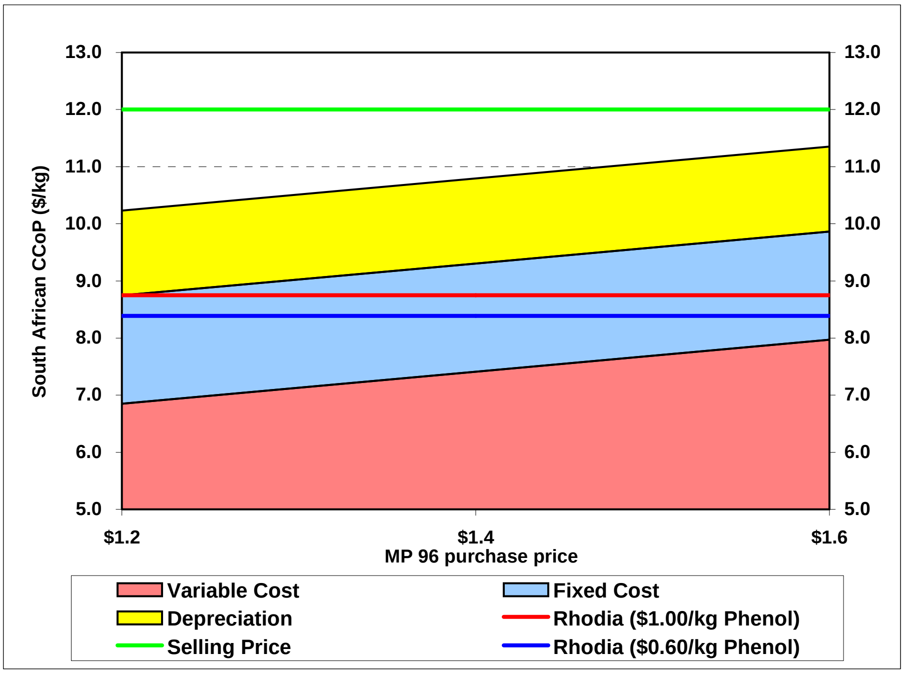
[25] Based on a depreciation cost of 10% over 10 years. The useful life of the plant is however expected to be at least 15 years.

Figure 22 further demonstrates this conclusion for the range of MP96 purchase prices $ 1.20 – 1.60/kg. As above, m-cresol is sold at $2.30/kg.

This graph indicates that a South African producer can only compete with Rhodia's cash cost of production on a variable cost basis over the MP 96 price range $ 1.20 – 1.60/kg. At a MP 96 price of $ 1.20/kg, the producer can cover fixed and variable costs, but not depreciation charges. Should Rhodia chose to depress prices down the $9.00/kg level, say to prevent a new competitor from obtaining market share, a South African producer would not be in a position to fully cover its fixed costs. At the lower purchase price of MP 96, more fixed costs will be covered.

FIGURE 22: Cash Cost comparison of SA producer vs Rhodia



On a stand-alone plant therefore, a South African producer would be unable to compete with Rhodia should vanillin prices be depressed. Clearly, the best scenario would be for vanillin to be produced as part of a basket of products where a portion of the fixed costs and capital charge can be absorbed by other products in the portfolio. In this instance, a South African producer would at least be able to cover its variable costs. The overall competitiveness would be best with a MP 96 purchase price of $ 1.20/kg and an m-cresol sales price of $ 2.30/kg. At these prices, and at a vanillin selling price of $ 12.00/kg, all production costs including the depreciation or capital charge are covered, with an additional contribution to profit of $ 1.77/kg.

5.3.4 Conclusion

The figure shows that a South African producer would not be in a position to compete on cash cost basis with Rhodia for any of the MP96 input prices and m-cresol selling prices considered. The low and high cash costs of $ 10.23/kg and $ 11.89/kg for South African based vanillin production substantially exceeds those achievable by Rhodia. With global commercial prices of vanillin being within the $ 9.00/kg to $12.00/kg expectation band, this would leave little margin for a South African producer to reward capital investment.

5.4 The Competitiveness of Menthol Production in South Africa

5.4.1 The CSIR developed Menthol Technology

The key to the competitive advantage of the CSIR Bio/Chemtek process over the cost leader Symrise commercialised process is the novel biocatalysis step in which menthol is generated as a single isomer.[26] Symrise, which used to be owned by Bayer, was formed by a merger of Haarmann and Reimer with Dragoco in 2002. Mbuyu Biotech (Pty) Ltd has the rights to license this technology package.

5.4.2 Competitive Analysis

In 2001, AECI carried out a competitive analysis of the synthetic producers, Symrise and Takasago, based on the variable cost of production of menthol. Techno-economic data were obtained from reliable AECI business intelligence networks as well as analysis of the patents of these two companies processes.

Information on the cash cost of production of the CSIR technology was obtained from Mbuyu Biotech. For confidentiality reasons, the cash cost of production of the menthol technology may not be divulged. This competitive analysis is therefore performed based on a percentage basis *vs* the cost leader and the company which has the most similar process to the CSIR technology *viz*. Symrise.

The assumptions upon which the analysis is based are as follows:

- The comparison is done on a cash cost of production basis. The cash cost of production includes variable, fixed and a depreciation cost (10%).
- The calculation of cash cost of production is performed in US$, as the business is US $ based.
- Fixed costs include manpower, maintenance (labour and materials), site and general overheads based on factors of capex; and selling and administration costs based on a factor of selling price.

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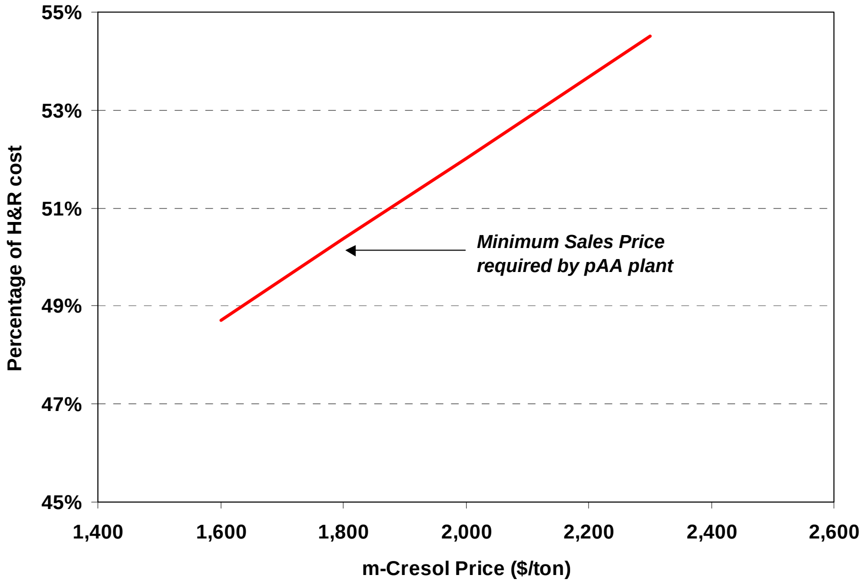
[26] CSIR Bio/Chemtek website

- Capital costs do not include utilities and infrastructure.
- The capital is for a stand-alone plant where utilities are bought in "over-the fence" at AECI prices.
- The variable cost of production competitive analysis of Symrise and Takasago's technologies have not been validated. Consultant information has been used to analyse the cash cost of production.
- The menthol mass balance and capital cost estimates have not been validated.
- The thymol mass balance and capital cost estimates have not been validated. Information has therefore been used as received.
- Analysis of the menthol technology on the basis of it being a ring-fenced facility.

The result of the analysis is shown in the figure below.

FIGURE 23: Comparison of the CSIR vs Symrise Cash Cost of Production



The benchmarking analysis of the pHB-pAA-OMC process to be world competitive indicated that a minimum sales price for m-cresol of at least $ 1,800/ton must be obtained. At this price, the CSIR technology has a cash cost of production of 50% of the Symrise technology. At a sales price of $ 2,300/ton, the CSIR technology still has a substantial cost advantage of 55%. This cost advantage is conferred by the novel bioresolution step, which is more efficient and less capital intensive than the Symrise process, resulting in a decrease in both variable and fixed costs.

5.4.3 Conclusion

At the prices required in order for the pHB-pAA-OMC process to be competitive, the menthol technology process has a substantial advantage over the Symrise process. The use of the naturally arising m-cresol from the pHB-pAA-OMC process therefore could be used to produce menthol in an optimised facility for the production of these products without rendering either of the two processes uncompetitive.