VCM and PVC in China

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There are essentially two routes for the production of vinyl chloride monomer (VCM). The acetylene route pioneered the introduction of VCM and PVC to the world in the 1950s and 1960s. However the ethylene route became increasingly favoured in the 1970s and 1980s. The superior economics of the ethylene route led to progressive closures of the acetylene-based plants, with the last one in West Europe closing in the mid 1990s and in the USA a few years ago.

The acetylene route seemed destined to disappear entirely, but it has had a remarkable renaissance in China in the last few years.

Most of the production of VCM in China today is not through the usual route of combination of chlorine with ethylene to make EDC, but through conversion of chlorine to hydrogen chloride (HCl) followed by combination with acetylene, as seen in Table 1. The acetylene is at present all made from calcium carbide, though there are plans to produce it in future from cracking of natural gas.

The production of calcium carbide is highly energy intensive and its use to produce acetylene in bulk for production of VCM has been abandoned in the rest of the world, but has been revived in recent years in China. The reason is the extreme cheapness of coal, as low as RMB70-100 per ton at the minehead in some of the remote provinces of the country, such as Nei Mongol or Ningxia, where labour costs are low. This in turn allows production of electricity as cheaply as Rmb120-150 per MWh.

The calcium carbide is made near to the coal mines and can be used locally to make acetylene, which is then combined with HCl from a local chlor-alkali plant to make VCM and then PVC. Alternatively the calcium carbide can be trucked to the eastern provinces and the same process undertaken near to centres of industry. In either case the VCM has to be competitive with VCM or PVC that is imported. Competition can also come from local producers of VCM using the ethylene route, but ethylene supplies are limited in China. The production chain from calcium carbide to VCM requires much less capital investment than the ethylene route.
and this, taken with the shortage of ethylene, means that the carbide route has been much favoured recently, especially when international VCM and PVC prices escalated rapidly in Q3 and Q4 2004. Calcium carbide based PVC capacity amounted to 67% of total PVC capacity at end 2005 and this proportion is due to rise to 72% by end 2007. Capacity figures for 2005-2007 are given in Table 2.1.

<table>
<thead>
<tr>
<th>Route</th>
<th>by end 2005 capacity</th>
<th>by end 2006 capacity</th>
<th>by end 2007 capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbide</td>
<td>6472</td>
<td>8950</td>
<td>10190</td>
</tr>
<tr>
<td>Ethylene and imported EDC</td>
<td>615</td>
<td>195</td>
<td>195</td>
</tr>
<tr>
<td>Imported VCM</td>
<td>1510</td>
<td>1610</td>
<td>1830</td>
</tr>
<tr>
<td>Captive/bought ethylene and chlorine</td>
<td>1080</td>
<td>1910</td>
<td>1910</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9677</td>
<td>12665</td>
<td>14125</td>
</tr>
</tbody>
</table>
Many plants came on stream during the course of 2005, so the end year capacity figure in Table 2.1 is considerably higher than capacity at the beginning of the year. We have calculated figures for true capacity available for January through December 2005, apportioning capacities for new plants pro rata according to the month of start-up. The result is shown in Table 2.2.

**Table 2.2**

CAPACITY OF PVC PLANTS IN CHINA IN 2005 (ktpa)

<table>
<thead>
<tr>
<th>Route</th>
<th>Consolidated Jan-Dec 2005 allowing for startups ktpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbide</td>
<td>5345</td>
</tr>
<tr>
<td>Ethylene and imported EDC (1)</td>
<td>735</td>
</tr>
<tr>
<td>Imported VCM</td>
<td>1390</td>
</tr>
<tr>
<td>Captive/bought ethylene and chlorine (2)</td>
<td>960</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8435</td>
</tr>
</tbody>
</table>

(1) Jinhua 80, Cangzhou 115, Tianjin Dagu 120, SCAC 420
(2) Qilu 600, Beijing No.2 160, Tianjin Dagu 200

Source: Tecnon OrbiChem

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**Table 3**

OPERATING RATES OF PVC PLANTS IN CHINA IN 2005

- For PVC made from calcium carbide and chlorine (46 producers): **89.9%**
- For PVC made from imported VCM (5 producers): **79.3%**
- For PVC made from ethylene and imported EDC **approx 75%** (Shanghai Chlor-alkali: 77.7%)
- For PVC made from captive ethylene and chlorine: Qilu Petrochemical and Beijing No.2 Chemical, average **95.8%**

Note: producers have been excluded which had expansions in 2005, or have more than one method of producing PVC, or have not been included in the production data of the National Bureau of Statistics.

Source: Tecnon OrbiChem
From production data that are available for 2005 (covering most but not all PVC producers), we have calculated the average operating rate for each of the four routes to PVC: the results are given in Table 3. It is noticeable that operating rates of plants that relied on imported VCM or imported EDC were around 10% poorer than for the integrated producers. Our estimates of actual production via the four routes are presented in Table 4.

It may be noted that our estimated production of PVC in China for 2005 is 7,110 kt. This is a higher figure than that published by the National Bureau of Statistics, namely 6,381 kt. However the Bureau did not include the production from 10 new plants that came on stream during the course of 2005, which between them we estimate produced around 350 kt. Adding this to the official total gives around 6,730 kt. It is thus possible that our methodology, based on combining Tables 2.2 and Table 3, is producing figures in Table 4 that are somewhat on the high side.

Table 4
PRODUCTION OF PVC IN CHINA IN 2005

- For PVC made from calcium carbide and chlorine = 4800 ktons
- For PVC made from imported VCM = 880 ktons
- For PVC made from ethylene and imported EDC = 530 ktons
- For PVC made from captive ethylene and chlorine = 900 ktons
- Total = 7110 ktons

Source: Tecnon OrbiChem

We attempt now to compare the costs to supply VCM to a PVC plant in China via these various routes. We do this in a series of diagrams in which production costs are related to crude oil costs in single line representations. It should be realised, however, that each line is an average of many different conditions, summed along the production chain. Each line in the graphics should thus be visualised as a ribbon or band along its whole length, to represent the divergences that arise from different conversion factors, plant sizes, technologies and so on.
Figure 1 represents production costs in countries that rely on ethylene from naphtha crackers, showing how they vary according to the price of crude oil. Corresponding electricity costs (the correspondence is not a precise relation) are used to calculate the cash cost of production of the Electro-Chemical Unit (ECU), which is divided by 2.10 to give the cost per ton of chlorine. (The factor 2.10 is a good long term average, but it can vary very widely according to the relative balance between caustic soda and chlorine in the world. In extreme cases the market value for chlorine can fall to zero.)

**Figure 1**

**PRODUCTION COST: DEPENDENCE ON CRUDE OIL PRICE**

*Ethylene, Chlorine, EDC*

Cash Cost Dollars per Ton

<table>
<thead>
<tr>
<th>Crude Oil Price $/bbl</th>
<th>Cash Cost Dollars per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>500</td>
</tr>
<tr>
<td>50</td>
<td>1,000</td>
</tr>
</tbody>
</table>

In Figure 2 we move to the position in China, showing the cost of production of calcium carbide according to the price of coal. Production costs are lowest in the remote provinces of north and west China and for the most part calcium carbide is made there and trucked to the eastern provinces, though there is also some production in industrialised provinces such as Shandong and Jiangsu.

In Figure 3 we show production costs of VCM in China for the case where VCM is made from ethylene but with imported EDC as the source of chlorine. This is undertaken by four companies in China, in plants close to eastern ports. There was a rapid decrease in costs during 2005, as international prices for EDC came down.

These costs can be compared with that of VCM production from calcium carbide and HCl, shown in Figure 4. In Q1 of last year, the carbide-based VCM could be produced in the coal-mining provinces at less than half the cost of imported VCM. Even for carbide-based VCM made in the eastern provinces, having to absorb the added cost of trucking of carbide over more than a thousand kilometres, production costs were some 30% lower than the price of imported VCM in Q1 2005. Since that time, however, international VCM prices have come down and are now on a par with carbide-route costs in the eastern provinces. This may take away some of the enthusiasm for building new carbide-based VCM plants in China, which are springing up like mushrooms in Nei Mongol.
Figure 2
PRODUCTION COST OF CALCIUM CARBIDE IN CHINA

Rmb per Ton

Coal Price Rmb per Tons

CaC₂ Production Cost
Other Costs

Electricity cost per ton CaC₂ (own production)

NW China
E China

Figure 3
PRODUCTION COST OF VCM IN CHINA
(1) From imported EDC + local Ethylene

Rmb per Ton

Q1 2005
Q2 2006

Other costs

Local Ethylene (0.22 tons)
Imported EDC (0.79 tons)
Economics for the acetylene and ethylene routes are compared in Figure 5.

**Figure 4**
PRODUCTION COST OF VCM IN CHINA
(2) From Calcium Carbide and Chlorine

**Figure 5**
PRODUCTION COST OF VCM IN CHINA

(1) From imported EDC + local Ethylene
(2) From Calcium Carbide and Chlorine
We now compare carbide-based VCM economics, which are fairly stable in China given the low cost of coal (though here too costs have gone up in parallel with world energy prices) with international costs in relation to crude oil prices.

Figure 6 summarises typical costs of international production of EDC and VCM. The upper two sloping lines illustrate the variability, according to the crude oil price, in international VCM costs for VCM made from naphtha cracker ethylene in the USA or Europe. The lower two sloping lines summarise the analogous position for EDC. For the full lines we have taken the chlorine price as equal to the caustic soda price, both being priced at the cost of the ECU divided by 2.10. For the dotted lines, we have taken the price of chlorine as zero.

![Figure 6](image)

**Figure 6**
PRODUCTION CASH COST: DEPENDENCE ON CRUDE OIL PRICE
EDC and VCM in Asia from imports ex USA/Europe made at Cash Cost

Dollars per ton

<table>
<thead>
<tr>
<th>Chlorine Price = Caustic Soda Price</th>
<th>Chlorine = Zero Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCM imported</td>
<td>EDC imported</td>
</tr>
</tbody>
</table>

Figure 7 illustrates the variability, according to the crude oil price, in international VCM costs for VCM made from naphtha cracker ethylene in the USA or Europe, costed as in Figure 6, plus the cost of shipping to China. We have also added the 17% VAT which is always included in Chinese pricing. (We have not added import duties, assuming that the PVC product is likely to be incorporated in exported goods.) Figure 7 illustrates the situation where chlorine is being costed in (at the international production point) at the ECU cost divided by 2.10.

It can be seen that VCM imported from naphtha-cracker based international producers cannot compete with carbide-based VCM made in East China, except in the extreme case that crude oil costs fall to about $20 per barrel. Even then, they are not competitive with VCM made in NW China. Local made VCM from imported EDC fares better, but crude oil prices need to be about $35 per barrel or below for such VCM to compete with carbide-based VCM made in East China, while crude oil prices need to be at $25 or below to compete with carbide-based VCM made in NW China.
Then in Figure 8 we show the similar situation but now with chlorine being given zero cost. This happens at times when demand for caustic soda is buoyant but demand for chlorine is depressed. These happen to be the conditions which apply right now. Figure 8 shows that the crude oil price will have to fall to around $30 per barrel, before international VCM and EDC

![Figure 7: VCM Production Cash Cost in China vs Imports](image)

![Figure 8: VCM Production Cash Cost in China vs Imports](image)
prices become competitive with carbide-based VCM in China, even in circumstances where world caustic soda demand is high and therefore chlorine prices are depressed.

It should be remembered that we have used as ethylene production costs those applying to naphtha crackers. Ethylene can be much cheaper when made from ethane derived from stranded gas, that is, in locations where the natural gas can be given only a low value through the high cost of moving it to market. In that case, which applies at a number of locations in the Middle East, the VCM can be made and shipped to China at levels that correspond to points on the horizontal axes in Figure 5 applying to much cheaper hydrocarbon costs – indicated by the thick bar in Figures 7 and 8.

[A point to remember in interpreting Figures 7 and 8 is that all the lines refer to cash costs of production. In practice the imported EDC or VCM price for a given crude oil regime can be much higher than the line represents – to the extent that prices are providing a margin above cash costs.]

We now use these carbide-based VCM production costs in China to derive the corresponding costs of the PVC into which they are made. We compare them in Figure 9 with international production costs of PVC derived from naphtha-cracker based ethylene. (We express all costs in US dollars and without VAT so as to be on a level playing field.) According to our calculation, the cost of PVC production in China will be lower than the international price whenever the international crude price oil is higher than around $25 per barrel as regards PVC made in NW China and higher than $35 as regards PVC made in East China. Indeed when crude oil prices are $40 per barrel and above, PVC made in China will have a $100+ per ton advantage over international PVC: with that margin transport costs can be covered to permit export sales. At still higher crude oil prices, PVC sales from China can be discounted below international levels in order to buy market share. In reality discounting may be necessary anyway, since there are some quality issues surrounding PVC made from calcium carbide.

PVC demand is growing fast in China in line with the boom in construction, so many new carbide-based plants are being built and planned. There is still a large import flow of PVC that local producers can aim to replace. With crude oil prices of $60-70/bbl, costs of PVC from naphtha-based ethylene are as represented well to the right in Figure 26. PVC produced in China from acetylene will be competitive with international PVC made from naphtha-based ethylene for as long as international crude oil prices remain above $40 per barrel. When oil prices are above $40 per barrel it is only PVC made from ethane-based ethylene in the Middle East, or from EDC imported from the Middle East, that will provide any competition to the Chinese VCM producers using calcium carbide.

In Figure 9 we also show the cost of production of HDPE from naphtha-cracker ethylene, depending on the crude oil price. It is seen that at very low crude oil prices HDPE has a lower production cost than PVC. However, as the crude oil prices rises above about $15 per barrel, PVC becomes increasingly competitive compared to HDPE.

Now that it seems that crude oil prices in future are likely to be $50-75 per barrel and above, it appears from Figure 7 that PVC will be considerably lower priced than HDPE. Thus PVC will be favoured over HDPE, for example in building construction and civil works, or even for shampoo and liquid detergent bottles in stores, where its properties enable it to meet requirements. Consequently we consider that PVC will have strong growth in a regime of high crude oil prices, taking some of the potential growth away from HDPE.
This will be particularly true for PVC made in China competing with HDPE made internationally if crude oil prices are high. Since China at present imports about 2.6 million tons of HDPE per year, there will be a strong incentive to use domestically produced PVC rather than imported HDPE (or other plastics) wherever that is possible.

This is confirmed by Figure 10, which shows the premium price that HDPE has had historically above PVC prices in east Asia, month by month over the last ten years, in relation to the crude oil price for each month. It is seen that at, say, $70/bbl for crude, HDPE has been showing a considerably higher price compared to PVC. Thus if crude oil prices remain high, PVC will be preferred over HDPE in end uses where the two compete. This fact is likely to give an added boost to the use of PVC, particularly in Asia, and most of all in China.
Figure 10
GAP BETWEEN HDPE and PVC PRICES in ASIA vs CRUDE OIL PRICE

Source: Tecnon OrbiChem

Asian HDPE HMW Film – PVC General Purpose
Plotted month by month 1997-2006

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