The Petrochemical Industry in Singapore

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THE PETROCHEMICAL INDUSTRY IN SINGAPORE

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# THE PETROCHEMICAL INDUSTRY IN SINGAPORE

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EXECUTIVE SUMMARY

1 Petrochemicals play an important role in the modern world: they are essential for the production of a diverse set of products, such as synthetic fibres and rubbers, plastics and resins, solvents and paints, explosives, and many more. In Singapore, the petrochemical industry is one of the fastest growing industries, fuelled by rapid economic development in the East Asia. It has strong linkages with the domestic economy, especially with the petroleum refining industry.

2 Growth in the petrochemical industry, however, is highly cyclical. This is due to the fact that investments in the industry are lumpy as producers try to exploit the benefits of economies of scale with large plants. Thus, years of shortages and high margins typically result in over-building and subsequent years of serious oversupply.

3 In particular, the strong demand and profitability experienced in the mid-1990s led to massive investment plans for capacity expansion, especially in Asia, in line with projections of strong growth in demand. Moreover, many governments in the region aggressively promoted the development of the petrochemical and other capital-intensive industries as a way to rapidly industrialise their countries. Consequently, ethylene production capacity in Asia expanded by almost twice the global rate in the period 1992 to 1997, and the region is expected to become the largest producer in the world by 2000. The onset of the Asian financial crisis in the middle of 1997, however, had derailed demand for petrochemical products. This, together with recent capacity additions across the region, hastened a downturn in the Asian petrochemical market.

4 In the next few years, Singapore's petrochemical firms appear well-positioned to benefit from the expected pick-up in regional demand. While some major projects have been postponed in the region, Singapore is still forecast to see strong capacity expansion in the petrochemical industry.
5 In the longer term, however, the prospects of Singapore's petrochemical industry depend very much on its competitiveness vis-à-vis others in the region. An examination of recent trends shows that Singapore's share in its traditional ASEAN market appears to be under threat, with its market share in Malaysia, its most important market for petrochemicals, sliding in the period 1992 to 1996. This reflected not just gains by major exporter Japan, but also significant inroads made by the ASEAN-3 countries. Output from massive capacity expansion in the ASEAN-3 countries was not only used to satisfy domestic demand, but was also exported. Singapore's share of the Chinese market, Asia's largest import market, actually declined in the period 1992 to 1996. This contrasted sharply with gains by Japan, South Korea and the ASEAN-3 countries. Nevertheless, in 1997, Singapore's export shares to most of the key markets rose significantly, following the start up of PCS' second cracker and associated downstream plants. This helped to boost the growth of Singapore’s domestic chemical exports despite depressed petrochemical demand from the crisis-hit regional economies.

6 Generally, Singapore's petrochemical plants are fairly competitive compared with others in Asia, given their large size and modern technology. Moreover, they are currently in a stronger financial position. In the longer term, however, the lack of natural gas reserves would be a negative factor.
1 INTRODUCTION

1.1 Petrochemicals play an important role in the modern world: they are essential for the production of a diverse set of products, such as synthetic fibres and rubbers, plastics and resins, solvents and paints, explosives, and many more. In Singapore, the petrochemical industry is one of the fastest growing industries, fuelled by rapid economic development in the East Asia. More recently, however, short-term prospects for the industry have dimmed considerably in the face of a huge capacity overhang and faltering demand amidst the Asian financial crisis.

1.2 This paper examines the trends and developments of the petrochemical industry in Singapore. Section 2 highlights the trends in the global petrochemical industry, as well as major players in the industry. Section 3 focuses on the development of the industry in Singapore, and the importance of the petrochemical industry to the Singapore economy. Finally, Section 4 discusses the future trends and the competitive position of the industry in Singapore vis-à-vis the other major producers in the region.
2 GLOBAL PETROCHEMICAL INDUSTRY: AN OVERVIEW

2.1 The petrochemical industry began to flourish in the 1920s, when petroleum producers and chemical manufacturers started to undertake research on how petroleum and natural gas might be used as a less expensive source of organic raw materials than coal. It has since grown to become a significant global industry today, with its products being used as inputs or raw materials in a variety of daily necessities and other industries, such as construction, packaging, clothing, electronics and automobiles. In the US, for example, shipments of industrial chemicals and the related rubber and plastics industry grew by an average of 6.9% and 8.0% p.a. respectively since 1960, compared with growth of 6.5% in overall manufacturing.

2.2 Growth in the petrochemical industry, however, is highly cyclical. The petrochemical cycle tends to last an average of 6-7 years with its last peak seen around the mid-1990s. This is due to the fact that investments in the industry are lumpy as producers try to exploit the benefits of economies of scale with large plants. Thus, years of shortages and high margins typically result in over-building and subsequent years of serious oversupply.

2.3 In particular, the strong demand and profitability experienced in the mid-1990s led to massive investment plans for capacity expansion, especially in Asia, in line with projections of strong growth in demand. In Southeast Asia, for instance, demand growth rates for base petrochemicals averaged 23% p.a. for 1993-1997, according to industry analyst Chemical Market Associates, Inc. Moreover, many governments in the region aggressively promoted the development of the petrochemical and other capital-intensive industries as a way to rapidly industrialise their countries. The petrochemical industry also offers a way for countries with their own oil and gas industries, such as Indonesia and Malaysia, to move up the value-added ladder. This development transformed the nature of the
petrochemical industry, turning countries that were net importers of petrochemicals into net exporters and causing a fundamental shift in the global supply-demand balance.

2.4 Thus, until the early 1990s, Asian ethylene production capacity accounted for less than 20% of total world production, with the region depending on excess petrochemicals in the US and Europe to satisfy its demand. However, with major capacity expansion due on stream over the next few years, Asia is expected to become the largest ethylene producer in the world by 2000, followed by the US and the Europe. In fact, Asia’s ethylene production capacity\(^1\) expanded by 8.9% p.a. in the period 1992 to 1997, almost twice the rate of global expansion. In spite of the Asian financial crisis, ethylene producers are expected to add another 5.4 billion tonnes of capacity between 1997 and 2000, equivalent to a growth rate of 7.7% per year. (See Table 2.1.)

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>Ethylene Production Capacity - Selected Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>'000 tonne per annum</td>
</tr>
<tr>
<td>Japan</td>
<td>6332</td>
</tr>
<tr>
<td>South Korea</td>
<td>3035</td>
</tr>
<tr>
<td>China</td>
<td>2322</td>
</tr>
<tr>
<td>Taiwan</td>
<td>845</td>
</tr>
<tr>
<td>India</td>
<td>552</td>
</tr>
<tr>
<td>Singapore</td>
<td>450</td>
</tr>
<tr>
<td>Thailand</td>
<td>315</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Total Asean-3</td>
<td>315</td>
</tr>
<tr>
<td>Total Asia</td>
<td>13916</td>
</tr>
<tr>
<td>Total World</td>
<td>69734</td>
</tr>
</tbody>
</table>

Sources: Jardine Fleming Research May 97, CMAI & internal forecasts

\(^1\) Ethylene capacity is used as an indicator for total petrochemicals capacity. This is the most capital-intensive product and manufacturers are inclined to maximise the output of derivatives.
2.5 Within Asia, Japan is the largest ethylene producer, accounting for about one-third of total capacity in Asia. South Korea and China are two other major producers. Together, the three countries make up about three-quarters of Asia's total ethylene capacity. This leaves countries in Southeast Asia with another 15% share, while India and Taiwan make up 5% each. (See Chart 2.1.) However, with Southeast Asian countries pursuing ambitious expansion plans, their share of Asian ethylene production looks set to rise to 22% in 2000. Taiwan and India are also embarking on massive capacity additions that will more than double their current capacity. (Appendix 1 provides a more detailed description of the petrochemical industries in each of the Asian countries.)

![Chart 2.1](image1)

2.6 The onset of the Asian financial crisis in the middle of 1997, however, derailed demand for petrochemical products. (See Chart 2.2.) Competition intensified greatly in subsequent quarters as Thai and South Korean petrochemical producers (which had sizeable foreign debt exposures) stepped up their exports aggressively, liquidating inventories to obtain much-needed foreign exchange. This was exacerbated by the huge build-up in capacity, as well as the sharp collapse in regional petrochemical demand. By mid-Jun 98, however, the flood of cheap petrochemical
products had eased as South Korean, Thai and Indonesian manufacturers faced cash flow problems which made it difficult for them to maintain feedstock supplies and forced them to reduce cracker operations.² (See Chart 2.3.)

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² In particular, South Korean petrochemical producers, which usually import about half of their demand for naphtha, saw imports of naphtha grind to a halt in December last year, when suppliers refused to accept their letters of credit.
2.7 In addition, anaemic demand has dragged down petrochemical netbacks since early 1997. (See Chart 2.4a.) Netbacks measure the profitability of processing raw materials, in this case, naptha, into petrochemicals. Thus, the Asian financial crisis and recent capacity additions across the region have hastened a downturn in the global petrochemicals cycle, with the industry currently undergoing inventory adjustment. (See Chart 2.4b.)

![Chart 2.4: US Petrochemical Industry](image)

Sources: Bloomberg, US Dept of Commerce

2.8 Over the next few years, the performance of the petrochemical industry is expected to vary across its different product groups. In particular, the demand for petrochemicals used mainly in durable goods, which are more sensitive to changing economic conditions, will be more severely affected by slower regional economic growth engendered by the crisis than those used principally to make non-durable goods. For instance, exports of PVC could be expected to shrink significantly, along with the collapse of regional housing and construction-related markets. Demand for petrochemicals used in non-durable goods such as low-density polyethylene (which is used largely for packaging) would also weaken, albeit by a smaller extent.
3 THE PETROCHEMICAL INDUSTRY IN SINGAPORE

Development

3.1 Prior to the start-up of Singapore's first petrochemical complex in the mid-1980s, the local petrochemical industry comprised a handful of small chemical companies producing basic chemicals. In 1984, the first petrochemical complex in Singapore – and in Southeast Asia – was brought onstream by the Petrochemical Corporation of Singapore (PCS). Located on Pulau Ayer Merbau, the complex included a naphtha cracker producing 450,000 tonnes per annum (tpa) of ethylene and 160,000 tpa of propylene, and 4 downstream plants producing polyethylene, polypropylene, ethylene glycol and other petrochemical products. Over the years, more world-class plants were set up, such as Mobil's aromatics complex in 1994 and Singapore Aromatics Company's aromatics complex in early 1997. (See Appendix 2 for a list of significant developments in Singapore's petrochemical industry, and Appendix 3 for further details on PCS and its downstream plants.)

3.2 In particular, petrochemical output received a strong boost in 1997 with the start-up of PCS's second cracker, which more than doubled ethylene capacity to 965,000 tpa, and allowed the development of a wider range of downstream petrochemical products. This massive capacity expansion helped to boost growth of petrochemical output to 83% in 1997. In the following year, however, the impact of the Asian crisis began to take its toll on regional petrochemical demand, causing a steep drop in petrochemical prices. As a result, growth of Singapore's petrochemical output moderated sharply in 1998, which was also due in part to the high base in 1997. Nevertheless, petrochemical production in early 1999 has been supported as new capacity from Sumitomo Chemical’s new acrylates complex came on stream.
Importance of the Industry

3.3 The importance of the petrochemical industry has increased significantly over the years. The industry's share of manufacturing output has risen from negligible prior to the start-up of PCS I in 1984 to 3.4% in 1997, reflecting strong growth in the industry. (See Chart 3.1.)

![Chart 3.1: Contribution of the Petrochemical Industry to Manufacturing Output, 1997](image)

3.4 Value-added per worker in the petrochemical industry was $0.15 million in 1997, compared with $0.08 million for the total manufacturing sector and $0.11 million for electronics. (See Chart 3.2.)

3.5 The petrochemicals industry has strong linkages with the domestic economy. Imported inputs constituted 57 cents for each dollar of industrial chemical (including petrochemical) exports in 1990, considerably lower than the averages of 69 cents for both total manufacturing and electronics.³ (See Table 3.1.) This is not entirely surprising, given that naphtha, the primary feedstock used to produce building blocks like ethylene or propylene, is mostly obtained from local refineries.

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³ If exports have a low import content, this would imply that the industry sources a considerable portion of its inputs from the domestic economy.
Employment and Productivity

3.6 In 1997, the petrochemical industry employed a total of 3,675 workers, or 1.0% of the manufacturing sector workforce. This is less than one-third of its share of manufacturing output of 3.4%, reflecting the highly capital-intensive nature of the industry. Net fixed assets per worker more than tripled from $0.44 million in 1996 to $1.59 million in 1997, following the start-up of PCS’ second naphtha cracker in April 97. This makes it even more capital intensive than the petroleum refining industry, with net fixed assets per worker almost 16 times the manufacturing sector average of $0.10 million. (See Chart 3.3.)
3.7 The export orientation of the petrochemical industry is also relatively high, although the petrochemical industry's ratio of direct exports to output has fallen from 68% in 1996 to 56% in 1997, as regional demand for petrochemicals slumped due to the crisis. This was lower than the ratio of 60% for the overall manufacturing sector and 76% for electronics. (See Chart 3.4.)
Major Petrochemical Exports

3.8 Over 90% of Singapore's petrochemical products (comprising plastics in primary forms and some organic chemicals) are exported to countries in the Asia-Pacific region. The ASEAN-3 countries of Malaysia, Thailand and the Philippines form our most important market, followed by the NIEs and China. (See Chart 3.5.)

Chart 3.5:
Singapore's Main Markets for Petrochemical Products, 1998
4 TRENDS AND IMPLICATIONS

4.1 In the next few years, Singapore’s petrochemical firms appear well positioned to benefit from the expected pick-up in regional demand. Some projects in the region have been postponed due to the crisis. Consequently, Asian ethylene production capacity is expected to rise by just 7.7% per annum in the period 1997 to 2000, compared with a previous projection of 11.8% per annum before the crisis. In particular, the ASEAN countries are forecast to see capacity expansion of 14% per annum, down from earlier plans of 36% per annum. Singapore, in contrast, is still expected to see strong capacity expansion of 22% per annum.\(^4\) Meanwhile demand in the region is forecast to grow by over 40% in the period 1996 to 2002, compared with global growth of around 30%.

Export Shares in Key Markets

4.2 In the long run, however, the prospects of Singapore’s petrochemical industry depend very much on its competitiveness vis-à-vis others in the region. Table 4.1 reveals two disturbing trends for the period from 1992 to 1996. One, Singapore's share in its traditional ASEAN market appears to be under threat. In particular, Singapore's share in the Malaysian market (which absorbed almost a quarter of Singapore's petrochemical exports in 1997) slid by 3.1% points to 15.2% in 1996. This reflected not just gains by major exporter Japan (in the case of the Thai and Indonesian markets), but significant inroads made by the ASEAN-3 countries. Output from massive capacity expansion averaging 49% per annum in 1992-1996 in the ASEAN-3 countries was not only aimed at import substitution to satisfy domestic demand, but was also exported.

4.3 Two, Singapore’s share of the Chinese market (including Hong Kong), Asia’s largest import market, actually declined in the period 1992-1996. This contrasted sharply with gains by Japan, South Korea and the

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\(^4\) This probably reflects the fact that petrochemical projects in Singapore are largely undertaken by large MNCs, sometimes with the Singapore government’s participation to help share the risk.
ASEAN-3 countries. Japan and South Korea, in particular, are closer to China and thus have the advantages of lower shipping costs and shorter time required for transportation. (See Table 4.1.)

Table 4.1:
Export Shares in Singapore’s Key Petrochemical Markets

<table>
<thead>
<tr>
<th>S’pore’s Key Markets</th>
<th>S’pore</th>
<th>Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>92</td>
<td>96</td>
</tr>
<tr>
<td>Malaysia</td>
<td>18.3</td>
<td>15.2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>7.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Thailand</td>
<td>4.5</td>
<td>6.0</td>
</tr>
<tr>
<td>China &amp; Hong Kong</td>
<td>2.7</td>
<td>2.4</td>
</tr>
</tbody>
</table>

* Note: Latest figures available for Malaysia are for 1996.

Nevertheless, in 1997, Singapore’s export shares to most of the key markets rose significantly, following the start up of PCS’ second cracker and associated downstream plants. This huge capacity expansion helped to boost the growth of Singapore’s domestic exports of chemicals and chemical products to a strong 18% in 1997 despite depressed petrochemical demand from the crisis-hit regional economies. As a result, Singapore saw a significant increase in its share of exports to Indonesia and Thailand from 1996 to 1997, while Japan and South Korea’s share in these markets either decreased or remained stagnant. For the Chinese market, however, export shares for Singapore and most of its major competitors rose from 1996 to 1997, reflecting the sustained Chinese demand for petrochemicals despite the crisis. In particular, South Korea and Thailand saw a significant expansion of their share of the Chinese market, which could reflect the surge of cheap exports from cash-strapped producers trying to liquidate inventories as domestic demand for their products slumped. In the longer term, the Asian financial crisis has resulted in the delays and cancellations of a number of petrochemical projects in the region, thus slowing the rate of planned petrochemical expansions among our regional competitors, in particular, Indonesia and Thailand.
Determinants of Competitiveness

4.4 Table 4.2 summarises the factors determining the competitiveness in the petrochemical industry. It shows that Singapore lacks natural competitive advantage in petrochemical production, although this is somewhat offset by technological factors.

<table>
<thead>
<tr>
<th>Country</th>
<th>Feedstock</th>
<th>Domestic Supply of Gas</th>
<th>Plant Size vs Global Average</th>
<th>Percentage of capacity added before 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Over 70% naphtha, some gas</td>
<td>Medium, exporter</td>
<td>50% below</td>
<td>61%</td>
</tr>
<tr>
<td>India</td>
<td>Naphtha/ Gas combination</td>
<td>Small, importer</td>
<td>20% below</td>
<td>36%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>All naphtha</td>
<td>Large, exporter</td>
<td>50% above</td>
<td>0%</td>
</tr>
<tr>
<td>Japan</td>
<td>All naphtha</td>
<td>Negligible</td>
<td>25% above</td>
<td>88%</td>
</tr>
<tr>
<td>Korea</td>
<td>All naphtha</td>
<td>Negligible</td>
<td>30% above</td>
<td>63%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Largely gas</td>
<td>Large, exporter</td>
<td>20% below</td>
<td>0%</td>
</tr>
<tr>
<td>Singapore</td>
<td>Naphtha/ Gas Combination</td>
<td>Negligible</td>
<td>50% above</td>
<td>47%</td>
</tr>
<tr>
<td>Taiwan</td>
<td>All naphtha</td>
<td>Negligible</td>
<td>Average</td>
<td>83%</td>
</tr>
<tr>
<td>Thailand</td>
<td>Gas and naphtha/ Gas Combination</td>
<td>Small, balanced</td>
<td>10% above</td>
<td>28%</td>
</tr>
</tbody>
</table>

Sources: Jardine Fleming, Oct 1997 and internal estimates.

4.5 Feedstock costs form the bulk of operating costs for petrochemical firms in Singapore. Generally, two types of feedstock may be used – natural gas (eg. ethane) or naphtha. Ethane’s high yields (more than 40% compared with 30% for naphtha) make it the cheapest feedstock. However, it is expensive to transport, limiting its use as a feedstock to countries with ready access to a source. This gives countries with natural gas reserves a distinct feedstock advantage. Although Indonesia and China have gas reserves, only Thailand and Malaysia have natural gas-based crackers. Petrochemical plants in Singapore presently use a combination of naphtha and gas.

4.6 Plant size is another key determinant as large plants enjoy economies of scale. Chart 4.1 shows that return on a 650,000 tpa cracker are around double those on a 300,000 tpa plant, and returns on a gas-based
plant are about double those on a naphtha-based plant. The size of Singapore's ethylene crackers compares favourably with those in the region. However, plants that recently came on stream in Korea and India\textsuperscript{5} are also considerably large.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{chart41.png}
\caption{Return of a Ethylene Plant, by Size and Type of Feedstock}
\end{figure}

Source: World Bank, 1990

4.7 Generally, newer plants would benefit from the use of better technology. Some 47% of Singapore's capacity was added before 1992, compared with over 50% for Japan, Korea and China. Plants in Malaysia, Indonesia, Thailand and India, however, are of newer vintage.

4.8 The level of integration is another important factor. Integration allows the optimisation of operations and helps to cut down on capital expenditure because there is very little intermediate storage. In Singapore, the Economic Development Board's strategy of increasing upstream ethylene capacity while introducing new chemistry chains has promoted greater integration within the industry, especially given the clustering of

\textsuperscript{5} India’s Reliance started up a 750,000 tpa ethylene cracker in March 1997, while Hyundai’s new cracker came on stream in Korea in late 1997, with an ethylene capacity of 550,000 tpa.
petrochemical companies on Jurong Island. Other producers in Asia are also moving in favour of large integrated crackers. For example, Shell is planning a massive $4.5 billion petrochemical complex in Guangdong, with an ethylene capacity of 800,000 tpa, to come on stream in 2003. Similarly, Malaysia’s first, fully integrated complex in Kertih is due for completion in 2001, and will boast of an ethane cracker capable of producing 600,000 tonnes of ethylene a year.

4.9 In sum, Singapore's petrochemical plants are currently fairly competitive compared with others in Asia, given their large size and modern technology. Furthermore, they are also currently in a relatively stronger financial position. In the longer term, however, the lack of natural gas reserves could be a negative factor.
### Appendix 1

**Characteristics of Petrochemical Industries in Asia**

|---------|-----------------------------------|-----------------------------------|------------------------------------------|
| China   | 3827                             | 4787                              | • Large gap between petrochemical production and demand despite rapid growth in the industry.  
• Asia's biggest importer, absorbing over a third of the polymer exports from Taiwan, Korea and Japan.  
• Chinese plants among the smallest in the world, due to the lack of capital and advanced technology.  
• However, petrochemical industry currently undergoing major restructuring in order to raise efficiency and improve competitiveness against foreign imports. |
| India   | 1150                             | 2250                              | • Characterised by chronic shortages in building blocks and downstream products which have slowed market development.  
• Most ethylene plants have capacities below 100,000 tpa, but there is a trend to replace these small plants with world-scale facilities. For e.g., Reliance’s 750,000 tpa cracker came onstream in 1997. |
| Indonesia | 520                             | 670                               | • Currently a net importer of petrochemicals, with Chandara Asri the country’s sole ethylene producer  
• Petrochemical industry badly battered by the crisis, with most major petrochemical projects delayed or cancelled due to financing difficulties.  
• May prove a fierce competitor in the long run, with their large oil and gas reserves and low labour costs. |
| Japan   | 7180                             | 7240                              | • Second largest petrochemical industry in the world, after the U.S.  
• Historically catered to domestic consumption, but demand today largely driven by export markets.  
• However, its share of exports is projected to decline in the coming years as new capacity comes onstream in the region.  
• No major capacity expansions planned over the next few years. |
| Korea   | 4870                             | 4870                              | • Major exporter of petrochemicals due to its high self-sufficiency ratios in most petrochemical products.  
• Producers are increasingly dependent on overseas markets, especially China.  
• Aggressive expansion plans announced after govt lifted regulations on cracker construction  
• However, petrochemical producers hard hit by the crisis due to their high foreign debt exposure, causing most plans to be cancelled or postponed. |
|---------|-----------------------------------|-----------------------------------|------------------------------------------|
| Malaysia | 630                               | 960                               | - Currently a net importer of petrochemicals, with 2 ethylene crackers and a third due onstream in H2 99. This will raise overall ethylene capacity by 60%.  
- The country’s drive to attract chemical investment has focused on petrochemicals as a means of adding value to its vast gas reserves.  
- Studies show it to be one of the lowest-cost locations for petrochemical production in the Asia-Pacific.  
- Despite downturn, investments in the petrochemical industry continue. For e.g. Petronas and Union Carbide are jointly investing in an integrated petrochemical complex in Kertih. |
| Singapore | 965                               | 1765                              | - The second of Singapore’s two naphtha crackers came onstream last May, more than doubling ethylene capacity to 965,000 tpa. Both are run by the Petrochemical Corporation of Singapore.  
- The crackers are closely integrated with downstream plants and local refineries, from which most of the naphtha feedstock is sourced.  
- Another world-scale petrochemical complex coming up – Exxon’s new cracker in late 2000.  
- No natural gas reserves, but arrangements have been made with Pertamina to obtain piped natural gas from West Natuna, Indonesia from 2001. |
| Taiwan | 1015                               | 2365                              | - State-owned Chinese Petroleum Corp (CPC) was sole producer for years, but Formosa’s new naphtha cracker is came onstream in late 1998, doubling Taiwan’s total ethylene capacity.  
- Structure of Taiwan’s vertically integrated petrochemical industry is changing as the focus of operation shifts to the upstream production of raw materials and downstream manufacturers relocate overseas.  
- Local plastic producers have increased exports to offset lower growth in domestic demand, leaving the petrochemical industry increasingly dependent on the mainland Chinese market. |
| Thailand | 1135                               | 1735                              | - Local production mainly used to satisfy domestic consumption, but the recent spate of capacity expansion has led to an increase in petrochemical exports.  
- Among them were Thai Petrochemical Industries’ 350,000 tpa cracker that started up in 1997 and Rayong Olefin’s 600,000 tpa naphtha cracker that came onstream in late 1998.  
- However, the crisis has resulted in a large number of projects delayed or cancelled, due to financing problems. |
Appendix 2
Significant Developments in Singapore’s Chemical Industry

1960’s  A handful of companies producing basic chemicals.

1980  
**SOXAL** - $24m expansion for the manufacture of industrial gases.

1982  
**Exxon Chemical Singapore** - $80m plant to produce additives (Paramins) for lubricating oil.
**Sun Ace Kakoh** - PVC stabiliser plant.
**Stahl Chemical Asia** - plant producing leather-finishing chemicals.

1984  
The $2b petrochemical complex (**PCS I**) on Pulau Ayer Merbau came onstream. The upstream company, **Petrochemical Corporation of Singapore (Pte) Ltd**, started production with three of the four downstream companies - **The Polyolefin Company (Singapore) Pte Ltd**, **Phillips Petroleum Singapore Chemical (Pte) Ltd** and **Denka Singapore Pte Ltd**. The complex has a capacity of 300,000 tpa of ethylene and 160,000 tpa of propylene. It also produces butadiene, acetylene, and benzene, toluene and xylene (BTX). The downstream companies will process these further into low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and other petrochemical products.

1985  
**Ethylene Gycols (Singapore)** - the 4th downstream plant of PCS I came onstream, producing ethylene glycols and ethylene oxide (EG/EO).

1986  
**Tetra Chemical** - methyl tertiary butyl ether (MTBE) plant.
**Ethoxylates Manufacturing** - non-ionic surfactants plant.

1989  
**Sumitomo Bakelite** - $30m plant for producing epoxy moulding compounds (used as an encapsulant for IC chips).
**Ishihara Sangyo Kaisha (ISK)** - $300m titanium oxide plant, with a capacity of 36,000 tpa (which was later raised to 42,000 tpa).
**Takasago** - opened a new factory, including an R&D laboratory for flavours and fragrances.

1990  
**Du Pont** - $50m Delrin polyacetyl resin plant
**Akzo Coatings** - US$5m specialty coatings plant.

1990-92  
**Kureha** - $70m PVC impact modifier plant

1992  
**Du Pont** - $230m Lycra elastane fibre plant

1993  
**Atochem** - $65m polystyrene plant
1994  
*Mobil* - $1.1b aromatics complex.

1995  
*Du Pont* - $160m Zytel Nylon 6,6 plant.  
*GE Plastics* - $70m engineering plastics compounding facility.  
*Givaudan-Roure* - $45m regional headquarters and manufacturing plant.  
*Sumitomo Bakelite* - opened another manufacturing line ($50m) for epoxy moulding compounds.  
*E Merck* - $10m technical centre.

1996  
*CRI/Criterion Singapore Manufacturing* - $30m plant to produce and regenerate catalysts for refiners.  
*Wacker Chemicals* (leading company in silicon products) - sealants manufacturing centre.

1997  
*Singapore Aromatics Company* - $1.4b aromatics complex opened in Feb 97.  
*PCS II* - a $3.4b project which includes a 2nd naphtha cracker (by Petrochemical Corporation of Singapore (PCS)) which will double Singapore’s existing ethylene capacity, a styrene monomer/propylene oxide plant (by Seraya Chemicals) and several downstream projects.  
*Hoechst Celanese* - $150m vinyl acetate monomer (VAM) plant.  
*Denka* - $43m general purpose polystyrene plant, with a capacity of 60,000tpa.  
*Toshiba Chemical* - $57m plant to produce epoxy moulding compounds, casting resins and insulating varnishes to support the electronics industry.  
*Air Products* - $35m air separation plant to supply oxygen, nitrogen and instrument air to Hoechst Celanese’s VAM plant.  
*SOXAL* - $30m specialty gas project to support the wafer fabrication industry.  
*Du Pont* - $400m adipic acid plant comes onstream.

1998  
*Sumitomo Chemical*, together with its affiliate *Sumitomo Seika Chemicals & Toa Gosei* of the Mitsui Group - $350m acrylates complex producing acrylic acid, acrylate esters, super absorbent polymers and methyilmethacrylate (MMA) monomers.  
*Chevron Chemical* – New fuel and lubricating oil additives plant with a 135,000 tpa capacity.  
The first worldscale detergent-inhibitor additives plant in the Asia-Pacific.  
*Lonza* - $180 mil plant to produce purified isophthalic acid  
*Santoku Merck* - Initially producing 3,500 tpa of high quality hydrogen, eventually to be raised to its full capacity of 10,000 tpa.

1999  
*Du Pont* - $140m Lycra plant.  
*Eastman Chemical* - $196m oxo chemicals manufacturing complex, producing 3 specialty oxo products sold primarily to the resins, coatings and vinyl compound markets.  
It will also include
a plant producing 150,000tpa of aldehydes, as well as plants for 2-ethylhexanol and n-butanol.

**Mitsui** - bisphenol-A plant with a 70,000 tpa capacity

**POVAL Asia** - $178 mil synthetic resin plant, capable of producing 40,000tpa of polyvinyl alcohol resin.

**Teijin** - first plant in Singapore producing polycarbonate resins

**Mitsubishi** - to produce 10,000 tpa of hydrogen peroxide, as a support facility for the wafer fabrication industry

**Hoescht Celanese** - plant producing acetate esters

**Exxon** - S'pore's third cracker coming onstream with an ethylene capacity of 800,000 tpa. $3 bil complex will include a 450,000 tpa PE unit, 275,600 PP unit and a 150,000 tpa oxo-alcohol unit

**Hoescht Celanese** - 500,000 tpa acetic acid plant to begin production. Will supply raw materials to Hoescht's downstream VAM and acetate esters plant

**Singapore Syngas** - $440 mil synthetic gases plant will supply Hoescht plant with carbon monoxide.

2001 Pact with **Pertamina** to begin delivery of natural gas from Indonesia's West Natuna sea via a 640 km pipeline. Singapore is expected to import 325 mil standard cubic feet per day of natural gas for the next 22 years.

**Mitsui** – phenol plant to come onstream, with a capacity of 200,000 tpa. Will source propylene from Exxon's cracker and supply raw material to Mitsui's bisphenol-A plant.

**Some Projects Pending/Delayed**

- **Asahikasei Tenac Singapore's polyacetal plant** - US$35m polyacetal factory with a capacity of 20,000tpa was originally planned for startup in 1999. However, construction has been suspended for a year due to the crisis.

- **Mobil**'s plans for a 800,000 ethylene cracker in 2003 are still pending, following its merger with Exxon in 1998.
Appendix 3
Linkages within the Petrochemical Industry

Source: Guide to the Petrochemical and Chemical Industry in Singapore 1997
Appendix 4
Glossary of Petrochemical Terms

**Acrylonitrile Butadiene Styrene (ABS):** An engineering resin used to make computer casings, bottles, vehicle panels, and housings for telephones, calculators, piping and fittings.

**Acetic Acid:** Largest use is VAM (vinyl acetate monomer) which is in turn used for poly-vinyl acetate (wood glue, adhesives) and poly-vinyl alcohol. Other uses include acetic anhydride acetate (used as solvents and inks).

**Acetone:** Made as a by-product from the manufacture of phenol. Used as a solvent and in the production of paints, explosives and synthetic rubber.

**Acetylene Black:** A base chemical for producing dry cells in batteries.

**Acrylic Acid:** Used as a monomer for acrylate resins. Produced via a two-stage oxidation of propylene. Used in production of dispersing aids, disposable diapers and superabsorbent personal care products.

**Acrylic Resins:** Acrylic acids are polymerised under the influence of heat, light and peroxides. Wide range of applications due to their clarity, brilliance and ease of forming.

**Acrylonitrile:** Intermediate used to produce ABS and AB rubber as well as acrylic resins.

**Aliphatics:** Straight-chain hydrocarbons, otherwise known as olefins. Ethylene, propylene, and butadiene, are the most important aliphatics and building blocks for most organic chemicals and synthetic materials.

**Aromatics:** Includes benzene, toluene and xylenes. Important end uses include plastic resins, fibers, rubber and gasoline. Also used to increase the octane rating of unleaded gasoline.

**Benzene:** The simplest and most widely used aromatic compound. Major end uses include styrenic plastics (polystyrene and ABS), phenolic resins, polycarbonate and epoxy resins, nylon, polyurethanes, synthetic rubbers and detergents.

**Bisphenol A:** Made from acetone and phenol. Most common use in epoxy resins and polycarbonate, which is a specialty plastic used for digital info storage systems (CD, DVD) as well as sheet & film applications.

**Butadiene:** Mainly is used to make synthetic rubber, primarily for tires and other fabricated items. Also used to produce latex, ABS resins, nylon fibers and resins.

**Choline Chloride:** Nutrient in animal feed.

**Cyclohexane:** Used almost exclusively in nylon production. 70% of world nylon is produced via cyclohexane. Other minor uses are solvents and plasticisers.

**Ethane:** Gas used as a feedstock for cracking process. Generally regarded as a cheaper feedstock than naphtha or gas oil. Usually extracted from natural gas stream.

**Ethoxylates:** Used for detergents, personal care products and specialty surfactants.

**Ethylene:** Basic building block of the chemical industry. Derived from the cracking of naphtha or gas oil. Demand for plastics (polyethylene, polyvinyl chloride, and polystyrene) accounts for about ¾ of final ethylene demand. Other important uses are for making antifreeze, synthetic fibers and rubbers, solvents and detergents.
Ethylene Glycol (EG): Primarily used in the production of polyesters and is derived from ethylene oxide (EO). Also used extensively as anti-freeze.

Ethylene Oxide (EO): Produced via the silver catalysed oxidation of ethylene. Almost all EO is used to produce EG. Other uses include detergent production.

Methanol – produced by reforming natural gas with steam. Major methanol derivatives are MTBE, formaldehyde, acetic acids, solvents, and various other chemicals. About half of methanol's final use is in polymers for adhesives, fiber and plastics. Also used in gasoline.

MBS resin: For the production of polyvinyl chloride (PVC) resin

Methyl methacrylate (MMA): Clear flexible plastic usually known by trade names such as "Perspex", "Lucite" and "Plexiglass". Produced using acetone, sulphuric acid and methanol as a starting material.

Methyl tert-butyl ether (MTBE): Used as a gasoline additive to boost the octane level.

Naphtha: Oil refinery fraction used as a cracking feedstock to produce ethylene.

Nylon: Synthetic fibre. Major use is carpet fibre and garments. Two major forms are Nylon 6 and nylon 6,6.

Olefins: See Aliphatics.

Orthoxylene: Aromatic compound used to produce plasticisers and phthalic anhydride.

Oxo chemicals: Aldehydes, alcohols and ketones produced from olefins such as ethylene and propylene. Uses include solvents and intermediates for paints and coatings.

Para-xylene: Derived from mixed xylenes by solvent extraction or selective crystallisation. Primarily used for the production of PTA.

Phenol: Second largest benzene derivative after styrene. Used to produce bisphenol-A and phenolic resins (used in adhesives).

Phthalic Anhydride: Major use as plasticiser. Also used for dyes and pigments.

Plasticiser: Added to plastics to improve the workability during fabrication. Able to impart various characteristics to the plastic or resin.

Polyacetal: A type of plastic used in car parts and electrical appliances.

Polycarbonate: Often referred to as an engineering plastic because of good clarity, toughness and heat resistance. Used for safety glass and space shuttle windows. They are often expensive and difficult to make. Extensive use in compact disk manufacture.

Polyester: Made from PTA and ethylene glycol. A synthetic fibre that can be blended and is relatively cheap to manufacture.

Polyethylene (PE): Most common and cheapest polymer. Variations include HDPE, LDPE and LLDPE. Used for food packaging and household applications.

HDPE (high density) is largest volume PE. Primary uses include blow moldings, mainly for containers and bottles, films and sheets, injection moldings etc

LDPE (low density) is second largest. Films and sheets, packaging and bats

LLDPE (linear low density) is fastest growing PE in recent years. Can be produced with less pressure and lower temperatures than required by traditional LDPE resin production processes. Used in film and sheet products, stretch and shrink wrap and film
Polyethylene Terephthalate (PET): Clear, tough plastic with good gas and moisture barrier properties. Applications include soft drink bottles and other blow moulded contains, while sheet applications are increasing. Produced from PTA and EG.

Polymerisation: Transformation of a monomer (single or small group) of molecules into a macro-molecule or polymer. Reaction usually carried out with a catalyst and heat or light.

Polypropylene (PP): Derived from the polymerisation of propylene. Fastest growing plastics resin for over 10 years with growing applications in the automotive, durable goods, and textile markets. Major end markets are consumer and institutional products, packages, furniture and furnishings.

Polystyrene (PS): Versatile plastic that can be rigid or foamed. Typical applications include protective packaging, containers, lids, cups, bottles, trays and tumblers.

Polyvinyl alcohol (PVOH): Used in textiles, adhesives, electronic components, surface coatings for paper and food packaging.

Polyvinyl chloride (PVC): Second largest volume plastic after PE. PVC demand highly dependent on housing and construction related markets which accounts for nearly 2/3 of demand. Construction uses include pipes, siding, gutters and windows.

Propylene: Base chemical extracted from cracker. Used to make polypropylene resin and chemicals like acrylonitrile, propylene oxide, isopropanol and cumene. Also used to make acrylic fibers; acrylonitrile-butadiene-styrene (ABS) resins; polyurethane resins; foams and coatings; unsaturated polyester plastics; solvents; and a blending agent in gasoline.

Purified Isophthalic Acid (PIA): An intermediate product used to make unsaturated polyester resins, coatings and paints, as well as PET bottle resins.

Purified Tetraphthalic Acid (PTA): Mostly used in polyester fibre production (75%) and for PET bottle resins.

Styrene: The most important benzene derivative in terms of volume. Primarily used to produce polystyrene (two-thirds of total use), followed by SBR and latex, ABS resins, unsaturated polyester resins and other plastics.

Styrene Butadiene Rubber (SBR): A synthetic rubber used primarily for tyre rubber formed by polymerisation of butadiene and styrene.

Toulene: A colourless aromatic liquid derived from catalytic reforming. Used as a solvent and as a chemical intermediate for explosives and high octane gasoline.

Vinyl Acetate Monomer (VAM): Derived from acetic acid. Used to make PVA (adhesives and coatings) and poly-vinyl alcohol (PVOH).

Vinyl Chloride Monomer (VCM): Produced from ethylene and chlorine. Virtually all is used for PVC production.

Xylenes: mixed xylene is primarily used in gasoline and as a solvent. For chemical uses, mixed xylene is separated into three isomers: paraxylene, ortho-xylene, and metaxylene.
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