CHEMICAL ECONOMICS OF CRACKING OPERATIONS

In this paper I will address the underlying economics of steam cracking to produce olefins in Australia and compare it to its peers in the Middle East, South East Asia and the USA. In Australia this is used for the production of high value plastics products (such as gas and water piping). The stoichiometry is:

$$C_2H_6 = C_2H_4 + H_2$$

The reaction is favoured by high temperatures (>800^oC) and low partial pressures which are obtained by adding steam to the system. The hot gases are rapidly quenched and then compressed to help separate the products. . A selective hydrogenation process is used to remove small quantities of acetylene also formed at high temperatures:

$$C_2H_2 + H_2 = C_2H_4$$

The purified ethylene is separated and then polymerised by a variety of processes to produce polyethylene. This product is then extruded to form the required commodity (e.g. pipes).

Ethane cracking is practiced all over the world at scales from 50kt/y to over 2Mt/y. The Australian industry comprises two operations, one at Botany (300kt/y) uses ethane from the central Australian gas fields has and one at Altona (200kt/y) which uses ethane from Bass Strait, supplemented with LPG from local refineries. These facilities are small compared with many operations in Asia, which unlike Australia have grown rapidly with the growth of China (Figure 1 and Table 1), for instance the Singapore cracking capacity is more than five times that of Australia.

Figure 1: Nameplate ethylene capacity in the Far East

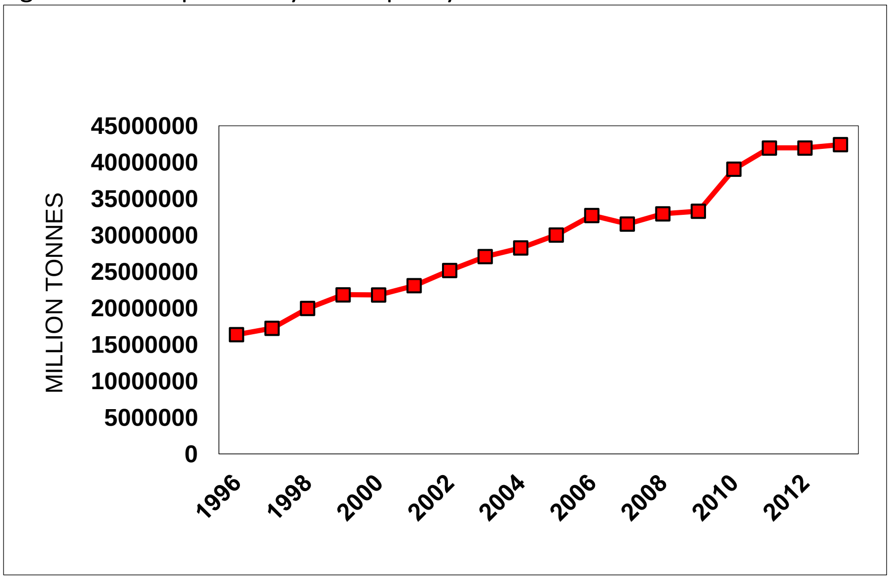


Table 1: 2013 Far East ethylene capacity (tonne/year) and 10y growth rate

	t/a	10y growth
AUSTRALIA	502,000	-1.0%
CHINA	13,778,000	67.4%
CHINA TAIWAN	4,006,000	41.0%
INDIA	3,315,000	27.6%
INDONESIA	600,000	8.3%
JAPAN	6,935,000	1.3%
MALAYSIA	1,723,000	3.7%
SINGAPORE	2,780,000	29.9%
SOUTH KOREA	5,630,000	12.6%
THAILAND	3,172,000	56.3%
TOTAL	42,441,000	

A typical ethane cracking operation has inputs and outputs as shown in Table 2:

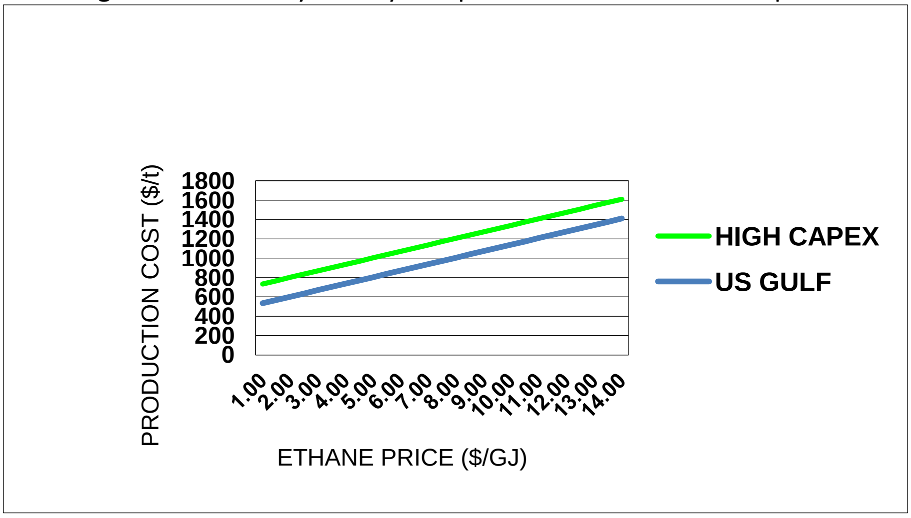
Table 2: Typical inputs and outputs for ethane cracking (wt/wt)

INPUTS	
Ethane	1.302
Ethane operating allowance (5.5%)	0.072
Furnace Fuel	0.660
Fuel operating allowance fuel (3%)	0.020
Total Inputs	2.053
OUTPUTS	
Ethylene	1.000
Propylene	0.034
Butadiene and other C4 olefins	0.034
Pyrolysis gasoline	0.022
Hydrogen	0.132
Methane	0.080
Total outputs	1.302

The complex free radical nature of the pyrolysis leads to products higher in molecular weight than the ethane feedstock. For small scale operations these are usually used as furnace fuel. For large scale operations integrated into a petrochemical complex, these materials are separated and result in by-product credits.

The impact on ethane price on the cost of ethylene production is illustrated in the lower line of Figure 2 for a ethane cracker of 500,000t/a ethylene capacity with a capital cost typical for a US Gulf construction of $850 million.

Figure 2: Sensitivity of ethylene production cost to ethane price



In many parts of the world (including parts of Australia) gas production cost is less than $2/GJ, recovering the ethane costs an addition $1/GJ so that in facilities which have access to such gas produce ethylene in the region of $600/t; for comparison traded ethylene prices are in the region of $1300/t. This is case in the Middle East which has attracted large scale investments in petrochemical plants to build on this feedstock cost advantage and as a consequence of shale gas developments in the USA is now driving a major resurgence of investment in the US chemical industry.

For Australia, traditionally ethane is priced on a scale relative to the price of crude oil (typically $6 to 8/GJ). This is obviously a major cost disadvantage relative to cracking operations in the Middle East and US based crackers. Furthermore, because ethane can be incorporated into LNG ethane cost could rise to match the export LNG value potentially over $12/GJ.

For Australia there is a further issue that of the cost of construction relative to other parts of the world. A common view is that construction costs here are 50% higher than in the US. This situation is reflected in the "HIGH CAPEX" line in Figure 2. This data shows that in order to produce ethylene in a new ethane cracker the cost of ethane feedstock has to be well below $9/GJ.

Australia is unique in the Pacific Rim of having imposed a carbon tax on emissions. For cracking operations this results principally from emissions from the cracking furnace. With an emissions charge of $25/t of carbon dioxide this adds about $55/t to the production cost. Applying such a tax without commensurate application by regional players would further inhibit investment in Australia.

As far as the present operations are concerned where the plants are older and have a significant portion of the capital written-off, the production cost would give a positive production margin but as this analysis shows there is little likelihood of significant plant expansions.

As this analysis shows the main issue is the price of feedstock. Given the uncertainty in the eastern seaboard gas market with the potential for methane and ethane being priced for the expensive north east Asia LNG trade, the obvious alternative is coal, the price of which for export is in the region of $3 - 4/GJ and lower than $2/GJ for domestic use. Coal based routes to olefins are now proven (in China 20Mt/y of coal based olefins facilities are planned) and offered by several major technology suppliers. Since methanol is an intermediate in this route, it can also be applied to stranded gas reserves in the remote regions of the country, however, such projects would always be at the mercy of a pipeline to the nearest LNG facility.

Technology under development concerns the production of ethylene by *catalytic* cracking. Propylene is already produced in this way by Deep Fluid-Catalytic Cracking which is a variant on a refinery FCC unit. The interest is to change the catalyst composition to incorporate more ZSM-5 zeolite and use naphtha as feedstock (rather than heavy fuel oil) to generate an olefin equilibrium in which ethylene is a significant component [1]. As well as this there is interest in the direct catalytic cracking of heavy oils including crude oil to ethylene [2], however, losses to coke is a significant problem.

Despite a long history, there are no commercially proven direct routes for the conversion of methane to ethylene. Oxidative coupling (OXCO process) is still the subject of much research with the major issue being the selectivity of the process to ethylene over the deep oxidation products - carbon dioxide and water [3]. Recently new proposals have revived interest in pyrolysis routes to acetylene but coke lay-down is the major issue to be overcome[4].

Unfortunately all these alternatives (other than coal based routes) require gas prices close to well-head production costs for viability.

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References

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