CHEMICAL ECONOMICS - CRACKING OPERATIONS

In this paper I will address the underlying economics of catalytic cracking to produce olefins and olefin derivatives in Australia and compare it to its peers in the Middle East, South East Asia and the USA. For this I will use as an example the steam cracking of ethane to ethylene used for the production of high value plastics (such as) piping. The stoichiometry is:

$$C_2H_6 = C_2H_4 + H_2$$

The reaction is favoured by high temperatures (>800°C) 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); note the Singapore ethylene capacity is more than five times that of Australia.

Figure 1: Nameplate ethylene capacity in the Far East

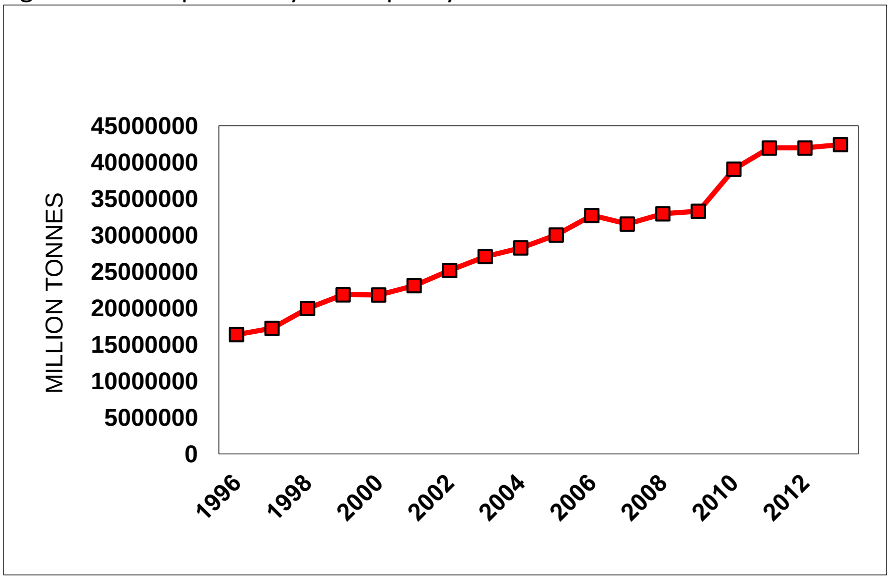


Table 1: 2013 Far East ethylene capacity (tonne/year) and 10y growth rate

	t/a	10y growth
AUSTRALIA	502000	-1.0%
CHINA	13778000	67.4%
CHINA TAIWAN	4006000	41.0%
INDIA	3315000	27.6%
INDONESIA	600000	8.3%
JAPAN	6935000	1.3%
MALAYSIA	1723000	3.7%
SINGAPORE	2780000	29.9%
SOUTH KOREA	5630000	12.6%
THAILAND	3172000	56.3%
TOTAL	42441000	

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

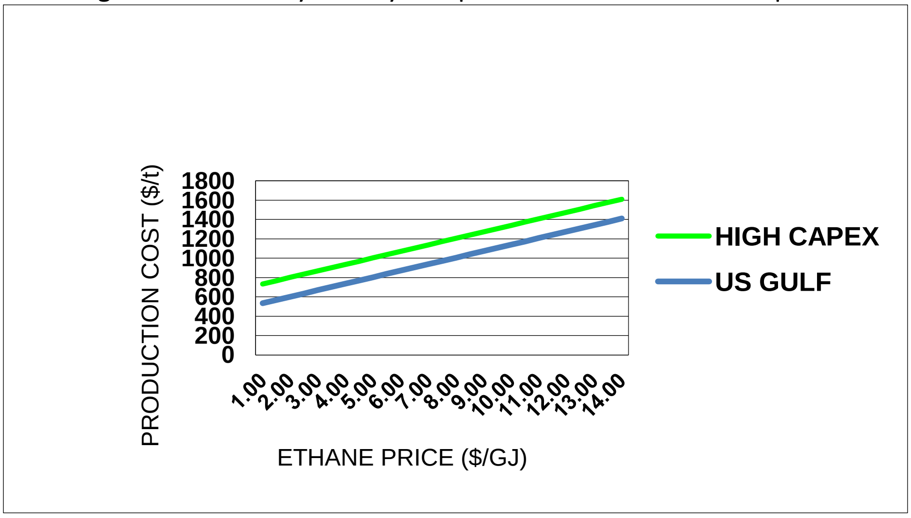
Table 2: Typical inputs and outputs for ethane cracking

INPUTS	
Ethane	1.302
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 to the operation.

The impact on ethane price on the cost of ethylene production are illustrated in 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 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. At this time of writing 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 below world parity prices, 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 for emissions costs adds about $55/t to the production cost. Carbon taxes are widely supported by the community. As seen in this analysis, 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 the analysis above shows there is unlikely to any likelihood of significant plant expansions.

In the world the most widely used feedstock is naphtha. As well as olefins (ethylene, propylene and butenes), naphtha steam cracking also produces aromatics which are core intermediates in the production of synthetic fibres (polyester and polyamides - nylons).

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 $4/GJ and lower than $3/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.

As far as cracking operations are concerned, there is considerable interest in 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. In these systems, however, losses to coke is a significant problem [2].

Despite a long history, there are no commercially proven direct routes for the conversion of methane to ethylene. Conversion of methane to ethylene by oxidative coupling (OXCO process) is still the subject of much, mainly academic, research with the major issue being the selectivity of the process to ethylene over the deep oxidation products - carbon dioxide and water [3]. Recently some proposals have revived interested in pyrolysis routes to acetylene where coke lay-down is the major issue to be overcome[4]. An interesting variant incorporates coal potentially facilitating the production of chemicals from coal bed methane and coal [5].

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

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January 2015

<u>References</u>

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