CHEMICAL ECONOMICS - AMMONIA - FERTILIZER AND EXPLOSIVES

The basis of the fertilizer industry revolves around the production of synthetic ammonia for the production of nitrogenous fertilizers. These fertilizers have revolutionised food production allowing seven billion people to exist on the Earth without frequent mass starvation events. Nitrogen fertilizers are particularly important for the growth of grass and cereal crops - wheat, rice, barley, sugar cane etc. - which are the main stables for most people.

Today, there are about 120 million tonnes of synthetic ammonia produced for fertilizer production. The main fertilizer product is urea, which, as a stable solid, can be transported in bags, trucks and shipped by bulk carriers from various production sites to the farm. Fertilizer is also delivered as ammonia itself, as a dilute solution, and can be shipped in specialist tankers (many of which also ship LPG) and as a compressed liquid piped to distribution centres.

There are other nitrogen fertilizers such as ammonium sulphate (produced as a by-product from processes using sulphuric acid) and ammonium phosphate. These fertilizers also deliver other important elements (sulphur and phosphorus) to plants. Adding potassium salts (potash) produces complex fertilizers delivering the three most important growth elements (N,P,K) for vegetables and flowering plants.

The primary route to uptake nitrogen in the plant requires oxidation of the ammonia to nitrate. Ammonium nitrate is therefore used as a solid fertilizer for immediate impact delivering nitrate directly to a plant. However, ammonium nitrate is dangerous and is used as an explosive. Its use as a fertilizer is restricted in many countries. In Australia, there is a large demand for blasting explosive in the mining industry and large quantities are produced for this purpose. So ammonia manufacturers in countries like Australia supply both nitrogenous fertilizers (as urea) and blasting explosives (as ammonium nitrate/diesel slurry).

Because the supply of fertilizer is critical to a countries well-being, feedstock, fertilizer production, distribution and price to the farmer is often controlled by central governments. This often takes the form of subsidies to producers and farmers so as to minimise the farm input cost. This restricts the extent of international trade so that the lowest cost producer is often excluded from the market. Australia is not in this camp and production here has to be competitive with other low cost producers around the world.

In the export trade, the lowest cost producer is often considered to be Russian/Ukraine operations based on the Black Sea and many other low cost producers, such as those in the Middle East, reference export prices as a premium or discount to the Black Sea price.

The major feedstocks used for the production of ammonia is natural gas and coal. These feedstocks are used to produce synthesis gas (a mixture of hydrogen and carbon monoxide) by steam methane reforming or partial oxidation (known as gasification in the case of coal). From methane the basic reaction is:

$$CH_4 + H_2O = CO + 3H_2$$

or by partial oxidation

$$CH_4 + 1/2O_2 = CO + 2H_2$$

The carbon monoxide is converted to hydrogen by the water-gas-shift (WGS) reaction and the residual carbon dioxide removed by an absorption process.

$$CO + H_2O = H_2 + CO_2$$

Nitrogen is added via a partial oxidation step of residual methane or using air in the partial oxidation/gasification reaction. This produces the ammonia synthesis gas required for the high pressure conversion into synthetic ammonia.

$$N_2 + 3H_2 = 2NH_3$$

In many facilities the carbon dioxide produced in the WGS reactor is added to the ammonia at pressure to produce urea:

$$2NH_3 = NH_2.CO.NH_2 + H_2O$$

One quirk in the production of urea is that substantially all of the carbon the methane feedstock ends in the product and thereby reduces the producers carbon emissions. However, on application by the farmer, the urea is oxidised to produce carbon dioxide and the nitrates required for plant growth so that overall there is no carbon emission benefit. In considering carbon taxes who pays for the emissions is moot - the manufacturer or the farmer.

Typical production costs are illustrated in Figure 1 for the production cost of gas based ammonia, urea and ammonia from coal. These are plotted as a fixed-variable with the variable the feedstock price (coal or gas) in energy units ($/GJ). The plots are for typical new world-scale operations; ammonia 850kt/y, urea 1500kt/y and coal/ammonia 1200kt/y. Approximate construction costs are for late 2015 with the gas based ammonia and urea plants having a three year construction period and the coal facility requiring four years. The estimate is for new gas based facilities with similar construction costs to Australia with a 30% loading over US Gulf construction costs. These are compared to a coal based ammonia facility in a western China location with a capital cost discount of 30% relative to US Gulf.

The gas based plants have a thermal efficiency of 65% and the coal plant 60%. No by-product credits are assumed, though in reality these could be significant if the facility could export power; coal processes also produce by-products such as ash for cement and sulphur.

The gas based ammonia plant has the highest unit capital cost ($/t) which determines the fixed costs and is hence the top line. The lowest unit capital cost ($/t) is for urea which contains a large quantum of unwanted material in the CO moiety in the molecule and is hence the bottom line.

Looking at top line which is the cost of ammonia production from natural gas (methane), it can be seen that at a gas price of $2/GJ (which is the typical mid 2016 gas price at Henry Hub in the US) the estimated production cost is about $350/t. This is below the quoted ammonia cost of $400/t in late 2015 but is about $50/t above the mid 2016 price; Table 1. Given that the cost of ammonia transport by ship is typically in the range $50 to $100/t, an Australian based plant with these statistics would be profitable against ammonia import. If gas was available below \$2/GJ, which may be the case in Western Australia, then export opportunities may still be profitable at the low current ammonia prices.

Unfortunately this is not the case with ammonia plants on the eastern seaboard where the volatility in the cost of natural gas (See *Chemistry in Australia* , October 2015, p. 36) as a consequence of the establishment of large export LNG facilities now results in wholesale gas prices of about US\$6/GJ (Aus \$7/GJ) which delivers production costs well above the world parity price at \$492/t. This production cost is above current ammonia import costs even on a cash cost basis when no capital charges are considered.

A similar situation occurs for the production of urea where high east cost gas prices currently being paid undermine the profitability of urea production against imports.

The cost of coal production in China (and in large open-cut mines in Australia) is well below \$2/GJ (typically \$30 to \$45/t) at the mine. Run of mine coal is often used for gasification and ammonia production. At these feedstock prices, and given the low capital cost of Chinese facilities, the ammonia production cost is below the world parity prices.

Clearly the production of ammonia for an Australian east coast fertilizer manufacture is at a crossroads. If the east coast gas crisis is not resolved in the coming months then we are likely to see facility closure and import of fertilizer into Australia. Without domestic production placing a cap on the prices charged by importers, prices will inevitably rise to farmers placing further stress on the agricultural industry.

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Table 1: Typical quoted Black Sea export prices and typical gas prices (US dollars)

	Second half 2015	Mid 2016
Ammonia (\$/t)	400	300
Urea (\$/t)	290	200
US Gas (Henry Hub) \$/GJ	2.0	2.0
East coast gas (wholesale)		~6

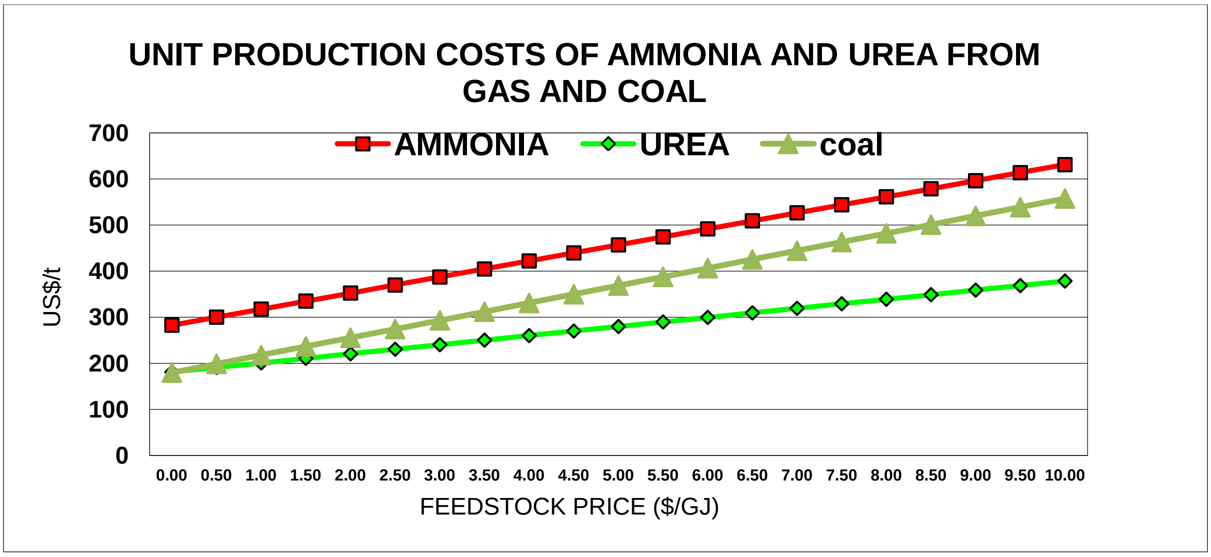

FIGURE 1: Influence of feedstock costs on ammonia and urea production costs.

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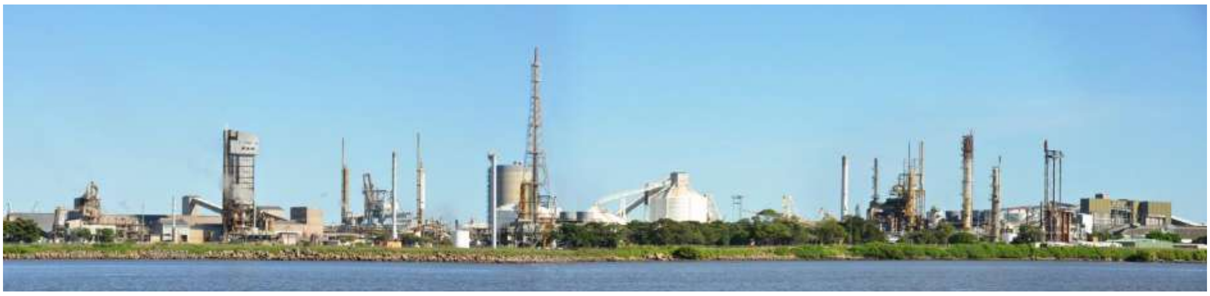

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“Ammonium Phosphate Plant at Phosphate Hill, Queensland – image supplied courtesy of Incitec Pivot Limited”