CHEMICAL ECONOMICS - P4 - IMPACT OF ENERGY COSTS ON AMMONIA PRODUCTION

In the previous papers I have shown how the underlying costs of energy impacts on the cost of chemical processing in the hydrocarbon processing and mineral processing industries. In this paper I discuss the cost of energy focussing on natural gas and examine the impact of energy prices on the cost of ammonia (fertilizer) production.

The Gas Problem

The general belief is that despite large and increasing gas availability and supply, the price of gas to domestic users is set to double or even treble and some geographic regions may experience restrictions in supply. We are primarily concerned with the gas supply on the eastern seaboard. Together these eastern states (SA, VIC, NSW and QLD) consume about 21.5 Bcm (billion cubic meters)[1] of gas which corresponds to about 800PJ in energy terms.

Concern with global warming has led to state governments mandating the use of renewable energy. In order to provide reliable continuous power to the grid, every watt of renewable energy (other than hydro) is generally backed up with a watt of open cycle gas turbine power (which has low efficiency). In the case of Queensland mandating the use of gas as a fuel source for power generation rather than coal has seen gas demand rise from 2.3 Bcm in 2001 to over 6.3 Bcm in 2013.

About 15 years ago it was proposed that deep, generally un-mineable coal resources of the Surat/ Bowen basins in Queensland could be used to produce coal seam gas (CSG) in competition to natural gas[2]. It was realised that these reserves if extended across all the coal basins, in theory, were vast[3] and could support export LNG provided the price was right. The past decade has seen a rapid rise in the price of LNG (especially in the North Pacific) so that the FOB price for LNG at Gladstone could support the generally higher production cost of CSG. This idea caught hold with some of the major players in the world LNG business and there was a rush to get on the bandwagon. This was sold and adopted by the Queensland government as a major export initiative. Today there are three major LNG projects nearing completion with two others also under active development and two others in the planning stage.

The 2015 demand for 16.9 million tonnes of LNG will require 1071PJ of gas per annum (c.f. 800PJ demand for the eastern states) and the future (2020) demand will be for 2536PJ.

Given that industry and government claim over 31,000PJ of CSG reserves (2P) at this point there is still, in theory, really no problem with the supply. Unfortunately, although companies and the Queensland government claim very high levels of 2P reserves for CSG resources, there is increasing

[1] Bureau of Resources and Energy Economics - 2014 Australian energy statistics data: http://www.bree.gov.au/publications/australian-energy-statistics/2014-australian-energy-statistics-data

[2] CSG has higher production costs to natural gas but the transport logistics in QLD make natural gas prices higher in that state than other gas consuming areas such as Victoria.

[3] Fifteen years ago, a gas shortage was predicted for eastern Australia for the 2015 onward period. It was proposed to pipe gas 3,500km from PNG to cover this shortfall but the large CSG reserve quashed the idea.

evidence that these estimates may be too high. Clearly the present developments in the Surat and lower Bowen are sweet spots for CSG production but whether the data can be extended across the basins is moot. Furthermore, under political pressure the Queensland government gas excised areas of the coalfields near towns and national parks from gas production and is under pressure to excise rich agricultural areas of the state.

The production cost of CSG is inherently high because (i) gas well productivity is low and a large number of wells are required, (ii) gas production is at near atmospheric pressure and the gas has to be compressed at high energy cost for delivery to Gladstone, (iii) CSG gas is spread over a large geographic area and a large network of pipelines is required, (iv) water is produced for many months prior to gas production and there is a substantial volume of water produced during the gas production phase, (v) the production of large volumes of saline water results in a high cost of disposal (by re-injection). The requirement of large low pressure pipeline infrastructure has been (and is) a boon for plastic pipe production.

However, the typical CSG production cost is higher than current industrial gas prices in Queensland and early contracts in the CSG business were probably based on the high productivity fields or sold into the high valued (and government controlled) power generation sector. In some areas the production cost of CSG will be too high even for LNG export.

Insufficient CSG can be supplemented by natural gas. This effectively integrates the domestic natural gas industry into the LNG export industry on the eastern seaboard.

The start-up of the LNG operations in Queensland represents a massive increase in demand. At the time of writing, the price of LNG in the export industries will support an $8 to $9/GJ gas price at Gladstone compared to the typical industrial prices in Queensland of $5/GJ and about $3.5/GJ in Victoria.

Furthermore, this is a clear price signal to exploration and production companies in eastern Australia; the target market for new gas developments is the LNG export market not the domestic market.

Impact on the chemical industry

Some commodity chemicals use natural gas a basic feedstock as well as for energy. A good example is ammonia but this is also the case for methanol (used for wood product adhesive) and cyanide (used for gold extraction). Ammonia is the prime building block for fertilizers by transformation into urea. It is also used to produce ammonium nitrate which is used as the basis of blasting explosive. The basic chemistry of ammonia synthesis is:

1. Stream reforming of natural gas to synthesis gas using nickel catalysts at high temperature (>800^oC):

$$CH_4 + H_2O = CO + 3H_2 \text{ and } CH_4 + 2H_2O = CO_2 + 4H_2$$

2. Secondary reforming of unconverted methane using air to produce more synthesis gas and introduce nitrogen into the stream:

$$2CH_4 + O_2/4N_2 = 2CO + 4H_2 + 4N_2$$

3. Water-gas-shift to maximise hydrogen production and move most of the carbon present to carbon dioxide:

$$CO + H_2O = CO_2 + H_2$$

4. Removal of carbon dioxide from the stream by absorption.

5. Removal of trace quantities of carbon oxides present by sacrificing some of the hydrogen present to produce methane which is inert in the ammonia synthesis - this is the reverse of the steam reforming reaction (1) and is conducted at low temperature:

$$CO + 3H_2 = CH_4 + H_2O \text{ and } CO_2 + 4H_2 = CH_4 + 2H_2O$$

These operations are conducted so that after drying the ammonia synthesis gas has the correct stoichiometry for ammonia synthesis:

$$3H_2 + N_2 = 2NH_3$$

The liquid ammonia produced in the synthesis can be sold or absorbed and diluted in water and used directly as a fertilizer. Commonly the carbon dioxide produced in the absorption step (4) is used to produce urea which is prilled or granulated into a solid fertilizer.

$$2NH_3 + CO_2 = NH_2.CO.NH_2 + H_2O$$

Ammonium nitrate is produced by oxidising ammonia to nitric acid then neutralising the acid with ammonia:

$$NH_3 + 2O_2\,(\text{air}) = HNO_3 + H_2O$$

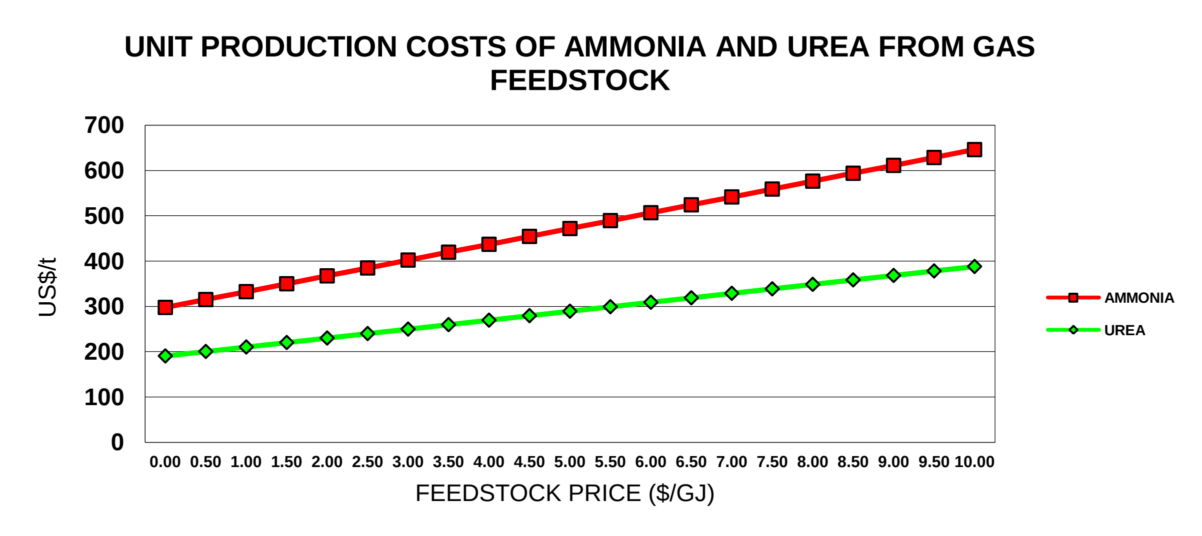
$$HNO_3 + NH_3 = NH_4NO_3$$

Overall the thermodynamic efficiency of ammonia synthesis in a standalone facility is about 60 to 65% using natural gas as a feedstock. The other 35 to 40% is consumed as fuel in the process particularly in the stream reforming process which is very endothermic and conducted at high temperature.

Using the methods described in previous papers the dependence on of ammonia synthesis on gas price is shown in Figure 1. The statistics are for a world scale operation producing 850kt/y ammonia at a capital cost of $1 billion. With typical traded ammonia price of $500/t, such a facility would require gas at$5.5/GJ or below for economic viability. Gas prices of $8/GJ as mooted would raise production cost to over $600/t and would not be viable against import competition. Fertilizer production in such a scenario would only be viable in old facilities with low capital charges. Clearly gas prices higher that $10/GJ would make ammonia (fertilizer) manufacture in Australia unviable.

This cost structure takes no account of carbon taxes and the like which considerably add to the production cost. An interesting case occurs with urea where the process carbon dioxide is captured within the product so that the facility would only be liable for emissions resulting from energy use of gas. However, on application, urea biodegrades with the carbon in the molecule going to carbon dioxide so there is no net benefit. Presumably in an ideal polluter pays world, the farmer would pay the carbon emission charge on the urea used.

Figure 1: Unit ammonia and urea prices sensitivity to gas price



Future Implications

Low gas prices in the US has seen a resurgence of investment in fertilizer production, including Australian based companies[4].

The case of methanol is similar. As a consequence of low gas prices in the US there is an increase in investment in this commodity, but again high domestic gas costs are likely to result in severely limiting this endeavour here. Worldwide methanol is increasing in importance as an intermediate for chemicals (acetates), fuels and olefins production. Low gas prices in the US is spurring increased interest in these end products further expanding the US chemicals sector.

For Australia, in the absence of US level gas prices, the only option would be to use coal as a feedstock which is considerably more capital intensive. One way around this problem is to use underground coal gasification of very deep coal seems to produce the intermediate synthesis gas. This is still being pursued by some companies[5] but because of regulatory restrictions most UCG projects in Australia have been abandoned or are being conducted at a very low activity level.

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Further Information:

For detailed technology description of ammonia synthesis and derivatives see "Catalyst Handbook", M.V. Twigg (ed), Wolf Publishing, 1989

[4] Incitec Pivot Limited, "New Ammonia Plant, USA, company announcement 21:01:2014
[5] For Example see Liberty Resources www.libertyresources.com.au