Workshop on Energy Efficiency and CO_2 Reduction Prospects in Ammonia Production

Initiating New Projects in the Ammonia Sector

presented by

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About the IFA Technical Committee

The IFA Technical Committee encourages the development and adoption of technology improvements that can lead to greater production efficiencies and reduced emissions, as well as better health and safety standards throughout the fertilizer industry. Our mission is to actively promote the sustainable development of efficient and responsible production, storage and transportation of all plant nutrients. The Technical Committee accomplishes these objectives through a variety of channels, including:

- Technical and policy-oriented information materials. The committee regularly conducts surveys and produces reports on key industry metrics, including the IFA Energy Efficiency and CO_2 Emissions Report, the IFA Safety Report, and the IFA Emissions Report. This work enables member companies to assess their operations over time, make comparisons with similar facilities on an established level of performance, determine the need for technology improvements and identify good industrial and management practices.

- Regular exchange of information on technology developments and industrial practices. A key role of the IFA Technical Committee is to encourage ongoing technical innovation in the fertilizer industry through the development, compilation and exchange of technical information between members, researchers, engineers, equipment suppliers and other industry associations. To this end, the committee organizes a Technical Symposium every other year to examine progress in the production technology of fertilizers. Each Symposium traditionally features the presentation of 30-40 new technical papers from member companies worldwide, providing members with information on the latest technological developments. In the intervening years, the committee holds a variety of meetings to assess current industrial practices and standards, with an eye toward identifying key developments of interest to members.

- Technical and educational workshops and special events. The IFA Technical Committee provides workshops designed for engineers working in the fertilizer industry, particularly those who have recently assumed new responsibilities, and for new engineers to increase their technical knowledge. These workshops (e.g. concentrating on nitrogen and/or phosphate fertilizer production) are designed to improve the participants' skills and broaden their vision and understanding of the entire industry, including technology, economics, energy use, safety and environmental stewardship. Workshops also provide engineers with an opportunity to exchange ideas, solve specific problems and improve plant operations and profitability.

- Education and advocacy. The IFA Technical Committee recognizes that customers, markets and regulatory environments are best served by clear and concise information on the fertilizer industry and its practices and products. Because the knowledge and expertise found within the fertilizer industry is the best source for this information, the Technical Committee endeavours to educate policymakers, standardization bodies, customers and the public on industry achievements, technological advances, voluntary initiatives and best practices. The committee also encourages universities and development centres to conduct research on fertilizer product development and production processes.

(as provided by the author for distribution in Ho Chi Minh City)

Initiating New Projects in the Ammonia Sector

Abstract

The ammonia market has enjoyed a sustained boom over the past three years. The main drivers for these high prices have been limited new capacity additions, some closure of capacity in North America and strong demand for ammonia. Going forward, there are new ammonia projects under construction, which should tilt the supply-demand balance toward oversupply and lead to declining prices. At the same time, production costs, particularly energy costs, have been rising and the industry faces the challenge of balancing declining prices and rising costs in the next five years.

The challenges faced by new projects are two-fold; securing a low-cost feedstock supply to ensure competitive cost of production, and keeping capital costs within reasonable bounds. The focus on feedstocks has intensified and producers are considering alternatives to the trend of focusing mainly on natural gas. Process developments have made heavy feedstocks a viable alternative to traditional gas-based plants. Heavy feedstocks such as coal and petcoke are relatively inexpensive compared to natural gas in many parts of the world. The drawbacks of heavy feedstocks are the higher emissions of greenhouse gases and other pollutants.

Previously utilising heavy feedstocks meant substantially higher capital costs for partial oxidation plants but this is no longer necessarily the case. The focus has shifted to controlling emissions, establishing economies of scale and minimising production costs. This paper will consider the merits of the major feedstocks options and the advantages and disadvantages of each.

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Initiating New Projects in the Ammonia Sector

About 80% of the ammonia produced globally is used in the manufacture of nitrogen fertilizers and about 50% of all nitrogen fertilizer consumption is accounted for by urea.

The question is often asked as to why we need nitrogen fertilizers when nitrogen composes almost 80% of the atmosphere. The simple answer is that atmospheric nitrogen is inert and not available as food for plants. It has to be “fixed”, that is combined in a form which plants can take up through leaf or root, to be useful to farmers. The best and cheapest way of fixing nitrogen is to combine it with hydrogen to produce ammonia (NH_3). The ammonia is then converted into more easily handled nitrogen fertilizers. The irony is that the major cost of ammonia production tends to be the hydrocarbon feedstock (generally natural gas) that is needed to source the hydrogen. The nitrogen comes free from the air.

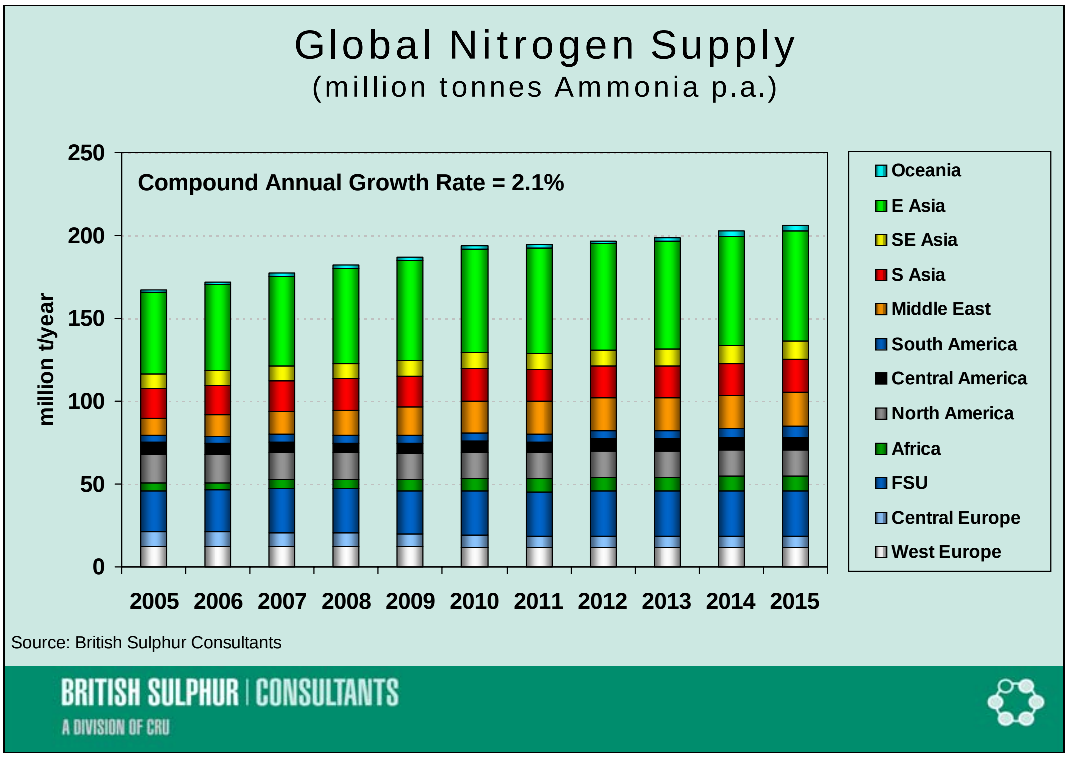
1. Ammonia Market Summary

This section gives a brief outline of British Sulphur’s outlook on the market. This section is not intended as a comprehensive discussion on all aspects of the global ammonia market but focuses primarily on the supply factors and the traded element of the product. In the context of examining the fundamentals of ammonia project decision-making, the analysis of the global ammonia supply situation provides perspective on the size of this industry and also the rate and geographic distribution of its growth.

1.1 Ammonia Supply

The following chart illustrates the geographical distribution of global capacity and provides a qualitative indication of growth.

Diagram 1



The salient points are:

- Ammonia capacity will be 205.9 million tonnes (product) by 2015, up 35 million tonnes on the 2006 figure of 171 million tonnes. It is important to note that the bulk of this new ammonia capacity will have downstream urea associated, thus the additional 35 million tonnes will not all enter the merchant ammonia market. This growth represents a compound annual growth rate of 2.1%.
- The bulk of the growth is taking place in East Asia, Middle East and North Africa. In the latter two regions this is mainly due to advantageous production costs thanks to low-cost gas availability. The capacity growth in East Asia, and more specifically China, is the result of the Chinese ambition for self-sufficiency in major fertilizer products. This capacity is unlikely to be classified as “low cost” and will be consumed within China.
- New merchant ammonia capacity being developed in North Africa and Middle East. Unlike China, where much of the new ammonia plants will simply be supplying downstream urea plants, there are some dedicated merchant ammonia plants emerging in North Africa and the Arab Gulf. These plants are focused directly on serving the rapidly expanding markets of South Asia (India and Pakistan) and Asian countries further East, such as South Korea, Taiwan and Japan.
- The new world-scale export-oriented plants due to come on-stream in the period 2006-2010 are evident in the upward trend in the chart. A consequence of this rapid growth will be an easing of the global supply-demand balance and a corresponding softening of prices. It is inevitable that such events will place pressure on high cost, uncompetitive plants globally.

Table 1. New Export Ammonia Projects.
(‘000 tonnes product)

Start-up	Plant	Country	Ammonia	Urea	Net Ammonia
2006	Burrup Fertilizers	Australia	760		**760**
2006	Safco IV	Saudi Arabia	1,089	1,073	**470**
2006	EFC II	Egypt	396	635	**30**
2007	NPC - Assaluyeh I	Iran	677	1,073	**60**
2007	Razi	Iran	677		**677**
2007	SIUCI	Oman	660	1,155	**-**
2009?	NPC - Assaluyeh II	Iran	677	1,073	**60**
2009	Ma’aden	Saudi Arabia	1,089		**400***
2009	EBIC	Egypt	660		660
2010	NPC - Shiraz	Iran	677	1,075	**60**
2010	Qafco V	Qatar	1,089	1,155	**425**
2006	Alexandria Fertilizers	Egypt	396	693	**-**
2009	MOPCO	Egypt	396	635	**30**
2009	Clico	Trinidad	610	1056**	**200**
	Total		**9,853**	**9,100**	**3,832**

* - Balance goes into DAP production
** - UAN production; only part of this value reported in urea total

1.2 Ammonia Trade

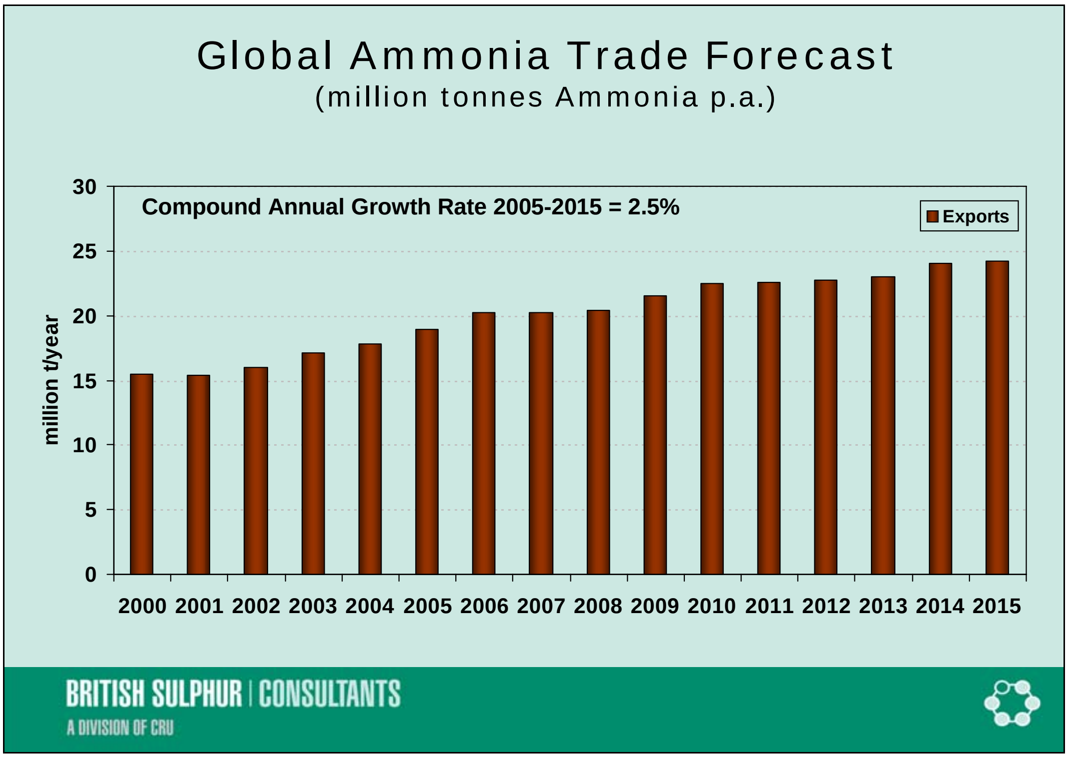
Merchant (traded) ammonia accounts for 13% of total ammonia consumption. Demand for merchant ammonia has increased from 11 million tonnes in 1993 to in excess of 20 million tonnes estimated in 2006. Importing ammonia is the preference of consumers whose requirement is too small to justify a captive ammonia plant (notably the technical sector), or where there is no low-cost natural gas available as feedstock. Therefore, as the technical sector has expanded, and as energy prices have risen, so has demand for merchant ammonia. Rising import demand from the USA has underpinned much of the growth of the merchant sector, as rising gas prices have been particularly detrimental to the domestic ammonia industry, and many operations have closed.

Merchant ammonia demand growth is also stimulated by rising ammonia demand in regions where new ammonia capacity cannot be economically justified. India, for example, has a huge fertilizer demand but hydrocarbon feedstock costs are such that it is virtually impossible to justify investment in Nitrogen capacity. Importation of ammonia is the solution that enables demand to be met.

Most ammonia trade is intra-regional, because of the high freight cost involved with shipping a hazardous product such as ammonia over long distances. For instance, West Europe exported 1.2 million tonnes of ammonia in 2006, but 1 million tonnes were imported by countries within the region. Similarly, North American exports amounted to 1.9 million tonnes in 2006, of which 1.3 million were from Canada to the USA. The remainders were inter-regional sales from Alaska to Asia. Even ammonia that is exported from one region to another often only travels relatively short distances. In 2006 67% of total exports from the Middle East were imported by India.

The international market for ammonia is thus well-defined by a hemispherical separation made by the Suez Canal. The Western Hemisphere is responsible for 75% of ammonia trade, yet represents an inverse proportion of the world's population. It is thus expected that the Eastern Hemisphere market will grow strongly in the coming years as the economies of Asia continue to grow.

Diagram 2



The outlook for trade in ammonia is:

- Ammonia trade will grow by 4.1 million tonnes to over 23 million tonnes in 2015. This growth is driven by the development of capacity at remoter locations, where low cost feedstock can be secured, and the need to ship this ammonia to the demand centres.
- Trade grows with capacity at about 13% of total production. The traded portion of the market is small but this is not surprising in light of the fact that most ammonia plants have associated urea consuming the output.
- Trade is driven mainly by demand growth in Asia and capacity substitution in North America.
- North America remains largest importer, with India the next largest. East Asian imports grow towards end of forecast as marginal supplement to growing domestic capacity in China.

2. Challenges to New Projects

The decision whether to proceed with an investment in new ammonia capacity is a complex one. As has been alluded to previously, the global trend of rising energy prices has impacted the production economics of ammonia production and make the cash cost of production a primary consideration for feasibility of new ammonia plants. Furthermore, the commodity boom in the past few years has resulted in a major boom in petrochemical projects generally. The increase in workload for the contracting and construction sector has lead to dramatic price escalation for ammonia projects.

2.1 Feedstock

The key points of the process may be summarised as follows:

- The starting point is the creation of a hydrogen stream, which generally comes from hydrocarbon and water (in the form of steam). Any hydrocarbon can be used, for example lignite, coal, heavy oil residues, fuel oil and naphtha have all served as feedstock for ammonia before natural gas became widely available. However, natural gas is the cheapest and most efficient feedstock for ammonia and accounts for more than 80% of the world's ammonia production.
- The hydrogen is split from the hydrocarbon and steam using high temperatures, pressures and catalysts to facilitate the reaction. The carbon from the hydrocarbon forms carbon monoxide (CO) and is then converted to carbon dioxide (CO_2).
- Nitrogen from the atmosphere is used to react with the hydrogen stream.

The critical points to mention in respect of ammonia manufacture are:

a) The high temperature and pressures and reaction endotherm for steam reforming required to drive the process consume energy. Roughly speaking, 75-80% of the gas consumed is used in the process to produce hydrogen and then ammonia and about 20-25% of the natural gas is used as fuel to drive the process.

b) Carbon dioxide, the by-product of ammonia production, is a greenhouse gas. It may prove a problem for ammonia producers if significant carbon taxes are introduced. The options for the carbon dioxide are:

- To vent it to the atmosphere.
- To consume it in the manufacture of urea, which combines the ammonia and CO_2 to form a solid fertilizer. Urea production generally utilises all the CO_2 generated on the tube side of the steam-reforming ammonia process.

- To use it in some other industrial process.
- Re-injection into oil wells to enhance oil recovery and/or sequestration of the CO_2.
- To liquefy it and sell it, for example to a manufacturer of sparkling drinks or as a coolant in a nuclear power station.

The truth be told, in any of the above cases the carbon dioxide will find its way into the atmosphere eventually, but it ceases to be the problem of the factory.

It is thus apparent that the critical element of ammonia production costs is feedstock. This is generally natural gas – more than 80% of world ammonia capacity is based on natural gas. This proportion continues to grow as practically all new capacity is gas-based and old, non-gas based capacity becomes uncompetitive and is gradually being phased out.

Over the last 20-30 years, we have seen the gradual closure of non-gas based capacity, mainly naphtha, fuel oil and coal. Practically all new plants were based on natural gas. This was because:

- Naphtha has become expensive as a higher-value chemical feedstock and its price is directly indexed to crude oil prices.
- Investment in cracking capacity has reduced the availability of heavy residues as refiners seek to maximize their revenues from each barrel of oil. The higher the oil price, the more investment in cracking is justified.
- These feedstocks produce more environmentally-damaging waste products; increased carbon dioxide, ash, tars and heavy metals.
- Coal conversion technologies were, until relatively recently, of quite low efficiency, 80% conversion as opposed to >95% achievable today.
- The cost of investment in a plant using heavy oil residues or coal is 1.5- 2.0 times that of a plant based on natural gas.

Natural gas was becoming more generally available and in many instances the cost was low compared to other feedstock options.

1.2 The Changing Energy Market

In regions such as the USA, West and Central Europe, but increasingly in developing countries such as Mexico, Pakistan or India, competition for gas is increasing as the power generation sector grows and as residential distribution systems are put in place. In the USA and Europe, gas prices have long passed the level at which reinvestment in the fertilizer industry is attractive. Closure is always a possibility and not only during extended market down-cycles.

The changes in the global gas business which are undermining many ammonia industries are:

(a) Feedstock gas served as a base load for the development of onshore and shallow water offshore gas fields in the 1970s and 1980s. The nitrogen and methanol industries in the Netherlands served as a base load for the newly developed North Sea gas fields. The same goes for the Louisiana feedstock industries, which justified the development of the shallow water gas fields off the US Gulf, and the Canadian nitrogen industry, which provided a base load for the new Alberta gas fields. As the years passed, a widespread gas grid was developed and now the feedstock sector, which was so important in allowing the development of North Sea, Canadian and US Gulf gas, only accounts for about 3%-4% of total gas use.

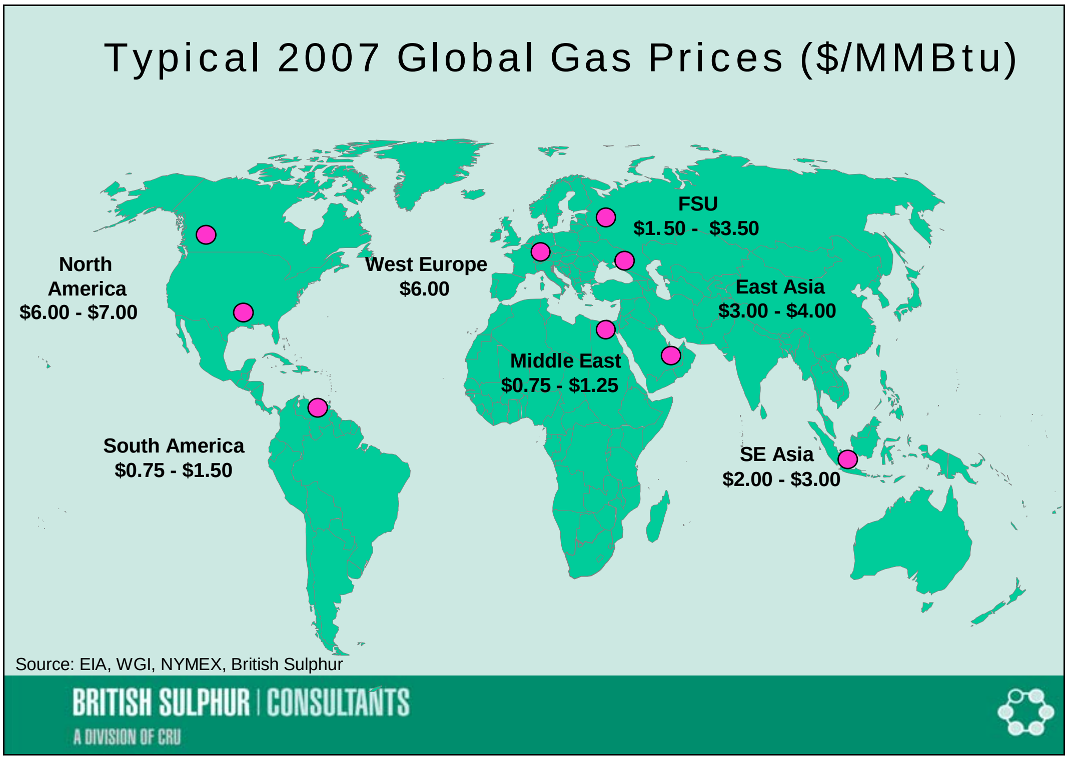
(b) Feedstock gas has often been given a strategic value, which reflects political policies rather than an open market value. For example:

- The European Union decided in the early 1980s (after the OPEC crisis) that the limited supply of North Sea gas was too precious to burn as a fuel. Therefore a special, low feedstock tariff was developed to protect its role as a chemical input, and power generation based on natural gas was discouraged. The new problems of greenhouse gas and pollution that arose in the 1990s saw a dramatic reversal of this policy and there was a rush to replace coal, lignite and fuel oil power plants with the new generation of gas-based cogeneration plants.
- In countries such as India, Indonesia and Pakistan, gas was offered to the fertilizer industry on attractive terms in order to promote the policy of self-sufficiency in food. In Indonesia and Pakistan the policy was achieved by government investment and a low gas price of around $1/MMBtu. In India, the Government did not adjust the gas price but offered a guaranteed return on any investment in nitrogen fertilizers. In countries with inadequate developed energy resources, such as India and China, this has resulted in significant market distortions.

(c) In practically all industrialised and populous countries where energy has to be imported, feedstock gas industries are coming into direct competition with power generators. This is as true in the United States and West Europe as it is in China or India. There are two general points to be made which apply globally:

- Power generation remains in the hands of state-owned monopolies in many parts of the world. In most cases, generators have the ability to pass on their costs to their customers. If gas costs $4/MMBtu, electricity will be priced accordingly. This is not the case for ammonia or methanol producers. The lowest cost exporters in the world – Russia and the Arab Gulf, establish the price for these products. Arab Gulf producers have access to gas at less than $1/MMBtu whilst Russian producers currently pay $1.2-1.5/MMBtu. Producers in North America, Europe or the Far East, purchasing expensive gas on the open market, simply cannot compete with imported ammonia, urea or methanol from a low cost importer unless the government is willing to offer either production subsidies or protective import tariffs.
- In the light of growing public concern for the protection of the environment, the development of new, clean power generation capacity based on natural gas has been actively promoted by many governments. It has gained a special status similar to that once enjoyed by fertilizers when famine was a major global concern.

Diagram 3



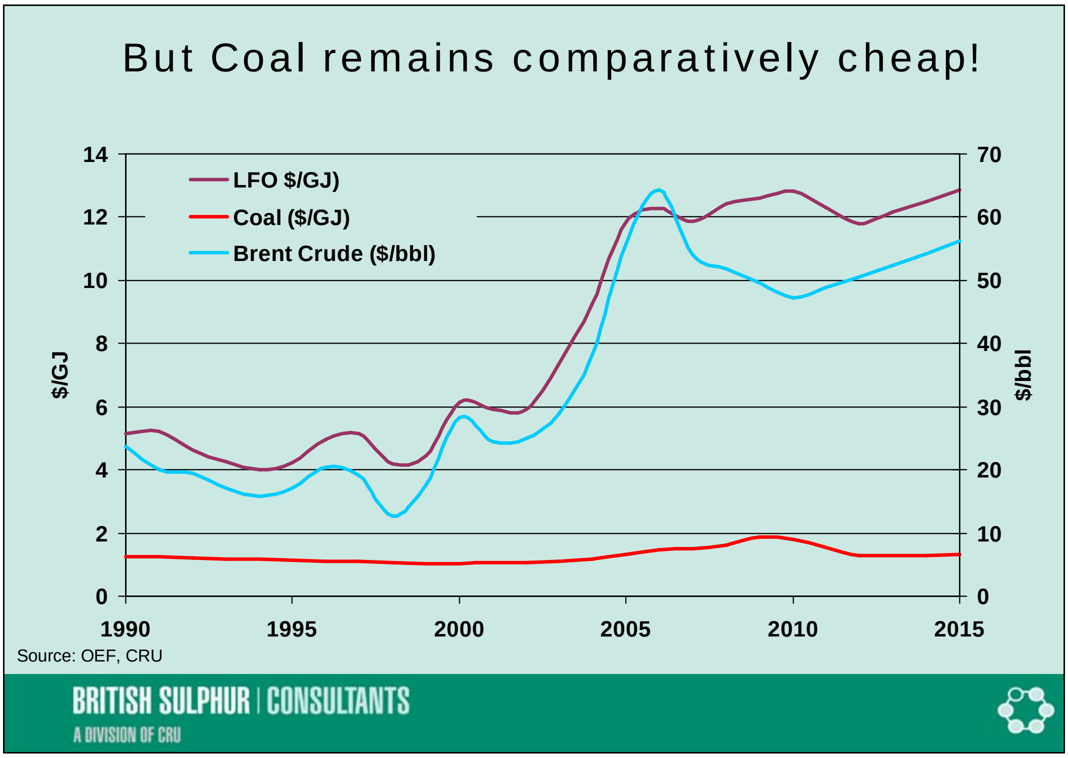
Ammonia and urea will increasingly be regarded as a relatively cheap form of imported energy. Energy will be diverted to nitrogen fertilizer manufacture in those countries with an abundance of resources whilst in populous countries, with limited or diminishing energy resources, the priority for energy use will be the residential, power generation and commercial sectors.

Those gas-rich countries with the most favourable market logistics will see significant investment in nitrogen capacity during the next 20 years. For ammonia, investment activity will be concentrated in the Caribbean (serving the US market), North Africa (West Europe and US market), the Middle East (Asian market) and South East Asia and Australia (Asia/Oceania and US West Coast market).

1.2.1 Alternative fuels to Natural Gas

As discussed previously, the heavier hydrocarbon feedstocks have been viewed as less preferred for ammonia production because of the higher capital costs for the partial oxidation plants that are required, plus the generally high costs and undesirable by-products associated with them. The competition for natural gas and improvements in gasification technology have lead to the heavier feedstocks being reconsidered and coal has emerged as an attractive alternative. The derivatives of crude oil remain too expensive for economic ammonia production but, as is depicted in the diagram below, coal has held steady while other products have become increasingly expensive.

Diagram 4



Turning to coal is not a perfect cure for the ammonia producer. While the low cost of coal offers big cost savings, coal does have drawbacks in the form of polluting residues and harmful by-products. Coal has the highest carbon to hydrogen ratio of all hydrocarbons and therefore produces more CO_2 than other feedstocks. As CO_2 emissions are increasingly in the spotlight for governments and environmental pressure groups, this by-product from coal is cause for concern. The other negative aspect to using coal is the contaminants that coal contains which are either removed from flue gases by scrubbing or remain as solid ash. These products are typically removed using water, which then must be treated and this adds to the cost of operation.

The following table gives a comparison between the various feedstocks. It must be noted that these are “traditional” energy consumption values and modern gasification technologies can improve on these values.

Diagram 5

Ammonia Process Comparison

Feedstock	Process	Capital Cost Index	Energy / t NH_3	CO_2 emission / t NH_3
Natural gas	Steam reforming	1	28 GJ HHV	1.6 t
Naphtha	Partial oxidation	~1.3 - 1.5	35 GJ HHV	2.45 t
Heavy Fuel Oil / Vacuum Residue	Partial oxidation	~1.5	38 GJ HHV	2.2 t
Coal	Partial oxidation	~1.5 - 2.0	42 GJ HHV	3.3 t

Source: *Modern Production Technologies* (Appl, 1997), British Sulphur Nitrogen Cost Model

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2.2 Project Capital Costs

The cost of building a new plant is going up. A new, world scale (2,000 – 3,300 t/d) ammonia plant will cost between about US$500 to $700 million 'turn key' depending on the technology used, the plant's location and if the plant is stand-alone or integrated. Typical interest rates are based on the London Inter Bank Offered Rate (LIBOR) rate plus points. An ammonia project could be financed today with 30% to 40% equity at between 7.0% to 7.5% annual interest. A 'risk' premium will also be required for plants built in countries considered to have significant political or monetary risk for the investor. This translates into a charge of $100 or more per tonne of ammonia simply to repay the debt.[1]. This has to be added to the cash cost of production and the sponsor then needs to decide whether the breakeven cost of the project will yield the necessary margins throughout the ammonia price cycle to meet the desired profit targets for the investment.

Building nitrogen capacity, even in a country with low feedstock costs, will be expensive and risky. Nitrogen prices have been at record highs over the last several years and with a forecast of a cyclical downturn, many projects will be delayed until market demand catches up with capacity and prices begin to expand once again.

The escalation in project capital costs has been down to a number of factors. Firstly many of the contractors and technology vendors are not US-based businesses and therefore do not operate their businesses on a US Dollar cost basis. Most projects are quoted on a US Dollar basis and the devaluation of the Dollar has resulted in these companies having to increase their (Dollar) prices to maintain their revenues.

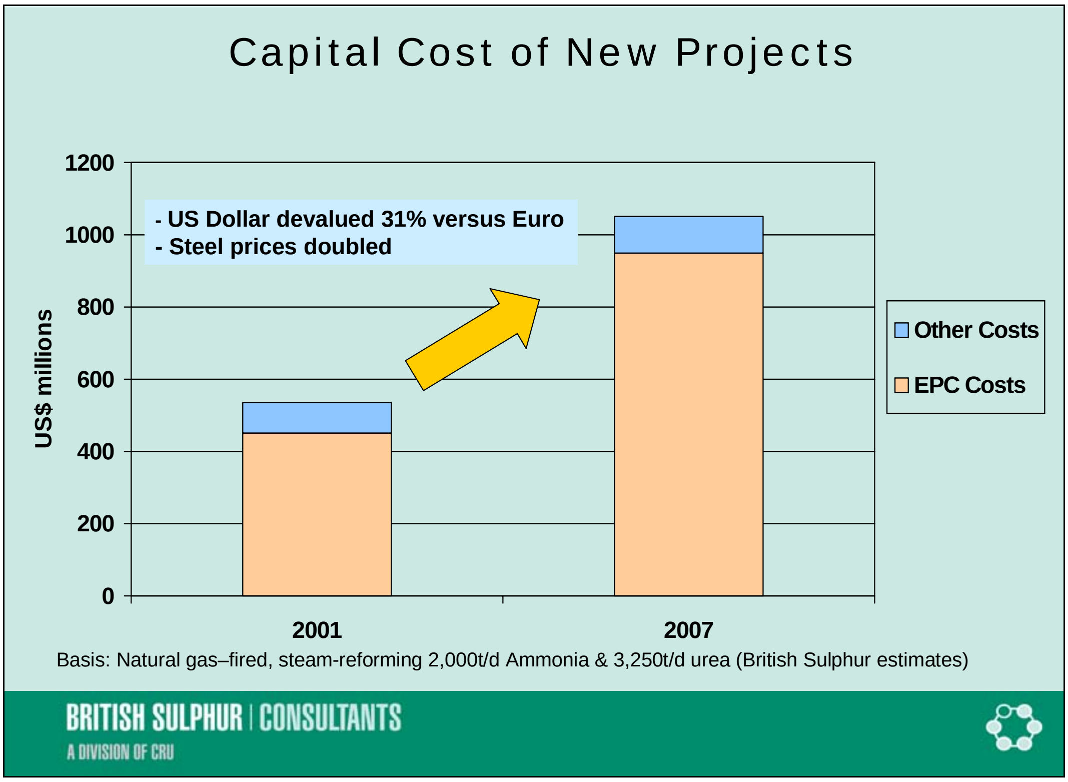
[1] Assumes a payback period of 10 years

Another major cost issue has been the escalation in international steel prices; doubling since 2003. This cost simply has to be borne by the project, thus the inflating cost of raw materials has directly increased project costs. The third factor has been the supply-demand issue for the fabricators of equipment for ammonia plants. The ammonia process operates at extreme pressures and there are only a handful of fabricators with the technical expertise to produce these various items, particularly for the large capacity units now being demanded for world-scale plants. Bigger nitrogen plants have moved equipment specifications into the realm of equipment being specified for petrochemical and LNG plants, thus intensifying the competition for fabricators' time. The rush to build new plants has seen the order books for the fabricators fill up and they have in turn raised their prices to extract a premium for their services.

Man-power costs have seen a similar escalation as engineers and contractors are in high demand to undertake all of the various projects under development currently.

The following chart illustrates the rise in capital cost escalation seen in the nitrogen industry over the past five years or so.

Diagram 6



3. Conclusions

The challenge for the prospective ammonia project sponsor is to mitigate the two cost elements of feedstock prices and capital costs. Dealing with the latter issue first, project capital costs by and large have to be endured and factored into the project budgets. The sponsor can make currency hedges if they are willing to assume currency risk exposure. Similarly, steel prices can be locked in to an extent by buying forward and using futures to assure prices. These processes do not lead to a lowering of the project cost but go some way to protecting against further cost inflation, which has been a recurring theme in ammonia projects in the past few years. The high costs of equipment and contractors have to be accepted or the project does not proceed.

It is on the side of feedstock prices that some interesting opportunities emerge. The traditional approach over the past two or three decades has been to base plants on the steam reforming of natural gas. Rising natural gas prices, especial in the Western World, has completely reigned in major ammonia project development, except in a few locations that has large gas reserves. The increase in gas prices, and therefore the increase in average cost of production for ammonia, has encouraged technology developers to consider alternative feedstocks. As discussed previously, oil-related feedstocks such as naphtha and to a lesser extent fuel oil have been ruled out because of the high cost of these products. This leaves coal and fuel-grade petroleum coke, which has hitherto been viewed as a low (or even negative) value waste product from the refining sector.

Unlike naphtha and fuel, which are comparatively simple to vaporize and combust (gasify) and process into synthesis gas (syn-gas) via the partial oxidation process, the solid feedstocks have required dedicated gasification equipment, which is a substantial investment cost. Furthermore the gasification process requires a large supply of oxygen, which is most cost-effectively produced using an air separation unit (ASU). The ASU is another expensive item, thus it is apparent how the capital cost escalation of these heavy feedstock-based plants occurs versus the conventional steam reforming process.

The cost of production can be reduced by using coal instead of the more conventional natural gas route, and is subject to a few trade-offs. The lower cost of production will need to compensate for the higher capital cost of the coal-based plant, at least until whatever debt is used to finance the project is disbursed. There are environmental challenges, summarised below, that also add to the overall cost of operations. Some of these can be controlled or eliminated by using scrubbing systems or via specialist waste disposal, and others have to be treated by methods such as carbon emissions trading for CO_2 unless there is some local use for the surplus CO_2 generated by the ammonia plant.

Environmental Challenges to using Coal:

- Carbon Dioxide production.
- Nitrous oxide gases (NO_x).
- Sulphur.
- Residuals – ash, tar and heavy metals.
- Volatile Organic Compounds (VOCs) and dust in handling. VOCs are a greater issue for fuel pet-coke.

In conclusion, coal-based ammonia production is a viable and indeed an attractive alternative to conventional gas-based processes in regions where gas is in short supply and expensive. It is not without its challenges but these can be mitigated and provided that the hurdle of high capital cost can be overcome, coal is likely to see increasing use as a feedstock for ammonia. As a coincidence, large reserves of coal are found in the high-cost gas regions with large demand for nitrogenous fertilizers, such as the populous countries in Asia.