FUTURE SUPPLIES OF PARAXYLENE FEEDSTOCK

A critical analysis - May 2004

Produced by:

PCI Xylenes & Polyesters
79 Portsmouth Road
Guildford
Surrey GU2 4BX
England

Suite 1208, Menara PJ
AMCORP Trade Centre
No 18 Jalan Persiaran Barat
46050 Petaling Jaya
Selangor Darul Ehsan, Malaysia

Jacobs Consultancy Inc
5995 Rogerdale Road
Houston
Texas 77072
USA

For all enquiries & feedback relating to this study, please contact Steve Jenkins at PCI Xylenes & Polyesters Ltd by phone +44 1483 302267 or email sjenkins@thepcigroup.com

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Introduction and Study Objectives

Our aim with this study was to thoroughly investigate the physical, structural and economic factors influencing the refining, aromatics and polyester markets and to assess whether there would be a sustained shortage of paraxylene feedstock, which if not addressed could restrict growth in the global polyester sector.

Our objective was to undertake an analysis of global demand for refined products and to run regional refinery models to calculate how much naphtha was realistically available to the aromatics sector for processing. From this we needed to analyse global reformer capacity and estimate within practical limits (maximum and minimum reforming cases) how much mixed xylenes, toluene and C_9s were potentially available to be developed into paraxylene production. It was necessary to go into individual reformers by company, by country and by region to work out where it was feasible for future paraxylene production to emerge. Our objective then was to identify those companies that had the appropriate feedstock balances and scale to justify a paraxylene production strategy.

We were also aware of the enormous potential of the Middle East as a low cost producer of paraxylene and therefore wanted to understand whether there was there a simple case in feedstock and economic terms to discount any further investments in other regions. We also wanted to understand why so many producers in the established production zones of Korea, South East Asia, Europe and even Japan were still seriously studying expansion projects and on what basis. Certainly as this detailed analysis was underway we noted a surge in local paraxylene projects in China, not only by State producers such as Sinopec and Petrochina, but also other foreign funded schemes seeking to develop paraxylene production from imported naphtha supplies through grassroots reforming. Our work enabled us to provide comparative production cost data for a variety of regional plants and technologies and given a likely cost curve profile, our objective was to present a logical scenario of paraxylene investments and trade flows on a global basis.

It is always difficult to summarize the findings, especially when the audience for this study comes from a wide cross section of the industry. However, the key objective of the study was to alleviate current concerns about the medium and longer term supply of feedstock and to allow clients to feel more confident about planning for further PTA capacities post 2006, knowing that sufficient paraxylene will be built eventually and highlighting likely locations and candidates for such growth. However, this study has also highlighted that the new generation of paraxylene plants will indeed be very competitive and through scale, catalyst technology developments and low cost feedstock is likely to reshape the global cost curve profile of the global paraxylene industry.

The methodology, as discussed below, sets out in more detail how we tackled the challenging questions of understanding the upstream fundamentals and how we married this together with our comprehensive assessment of the downstream markets. This is a unique attempt to offer a considered well researched opinion on what lies ahead for the global polyester business and we await feedback from all our clients over the coming months, as they each digest the contents and conclusions.

We wish to thank all of our clients who have supported this study effort and we hope this helps you to understand the upstream side of paraxylene. We welcome your questions on this study and look forward to discussing your plans for the future.

Study Layout

Section 1 discusses refined products demand, the resultant demand for crude and changes in refining configuration. It takes a look at global gasoline demand by region from 1987-2015 and assesses gasoline trade patterns as well as the impact of gasoline specifications on petrochemical supplies in relation to aromatics content. We complete this section with a range of price forecasts for crude oil, naphtha, other refined products and BTX. This allows us to define likely refinery margins over the study period.

Section 2 is an analysis of the main paraxylene precursors. We look at typical refinery configurations in the US and Europe and assess typical gasoline component makeup and composition to work out how much contained xylenes and toluene remains in the gasoline pool. We introduce the scale of reformers worldwide by region and by type and we have used our reformer database to estimate the yield of mixed xylenes from such reformers. This leads on to a global mixed xylenes production and consumption forecast split by key region and from this we tabulate which global refineries having worldscale reformers of over 40,000 barrels per day, are still not producing mixed xylenes for petrochemical use. This analysis also includes a listing of new reformers under construction or at the planning stage.

With this background we then include our discussion on global paraxylene supply and demand for the period 2004-20 and relate the issue of naphtha supply potential to new paraxylene capacity being planned, or probable for the same period. This includes our assessment of global supply/demand of naphtha by key region and key Asian country, identifying naphtha use in 2003 by key petrochemical sector. We conclude with our forecasts for naphtha supply and demand comparing 2003 with 2015.

Section 3 discusses paraxylene production economics in some detail, but initially assesses the type of reformers employed in a modern complex and a description of the main paraxylene technologies. We discuss the use of toluene disproportionation as a route to paraxylene and discuss the variety of technologies available. Similarly we discuss transalkylation as a route for selectively converting C_9s and other heavy aromatics including toluene into mixed xylenes and benzene.

Section 4 brings together the above analysis and reaches set conclusions on the issue of feedstock choice constraints for paraxylene. We answer where we believe new mixed xylenes and paraxylene will be built and why, leading to a series of solutions that can be pursued to recover paraxylene. This then leads on to our analysis of the paraxylene cost curve, looking at which complex in which configuration of technologies and in which region, makes most commercial sense. This has implications for capital cost investment, regional cost comparison, paraxylene trade and downstream polyester pricing.

Methodology

Refined Product Supply/Demand

Our analysis of feedstocks for paraxylene begins with a refined products demand forecast. Based on historical growth patterns and a review of current and forecast macroeconomic and structural trends, refined product demand forecasts were prepared for three OECD regions (North America, OECD Europe, and OECD Pacific) and five non-OECD regions. Rather than include China in non-OECD Asia, the country was handled separately to differentiate trends in China from the rest of the region.

Diesel fuel, jet fuel, and gasoline demand forecasts are relatively straightforward. Jet fuel and diesel demand is mostly a function of economic trends and - in the case of jet fuel - consumer sentiments regarding flying. Gasoline demand depends on the nature of the automobile fleet, the economy, and population. Home heating oil and cooking kerosene demand depends on specific situations inside a region. As an example, in most of the OECD, domestic use of distillate or LPGs is declining or effectively gone. In some non-OECD areas, demand for these fuels is on the rise. Thus, our forecast must consider such trends on an individual basis. Residual fuel oil demand has two major components: bunker fuel for ships and industrial/power use. In general, the bunker market grows with the economy. Residual fuel use, however, especially high sulphur product, is waning around the world.

Naphtha demand, which is obviously key to this analysis, is the most complex. As will be discussed below, demand for aromatics production depends on the demand for each separate product (benzene, toluene, each of the xylenes, solvents, etc.) and the technology employed. Demand for naphtha as ethylene feed is a function of ethylene demand and feedstock competition. There is also a small component of demand for other uses such as power or synthesis gas chemicals.

Given a demand slate, it is necessary to define the amount and quality of crudes that will be processed in the future. This was done based on historical production trends and forecasts of production declines for major producing regions such as Alaska, the US lower 48, and the North Sea. Iraq and the primary OPEC producers have been forecast to "fill in the gap."

We must now determine the kind of refining capacity that will be required to match the supply of crudes with product demand. Regional refinery balance models were prepared for the ten regions of interest plus an overall "world model." These were first "tuned" to current data then used to forecast required construction to meet demand trends. In some key areas, complex linear programs were used to address gasoline composition issues. These models were also used to simulate "typical" refineries in regions to evaluate their ability to supply mixed xylenes.

Naphtha Demand

Within a refinery, there are several uses for naphtha:

- For heavy naphtha, circa 160° to 400°F (71° to 204°C), most is sent to reformers and converted into reformate, a high octane gasoline blending component. A portion is

sold separately as heavy naphtha for aromatics production. In our balances, we have counted such naphtha as being "sold" by the refinery even when the aromatics producing units are inside the refinery or owned by the same operator.

- Light naphtha is sold for petrochemicals, isomerised to produce a gasoline blendstock, or blended directly as gasoline.

We recognize that several large operations around the world fractionate natural gas liquids and produce naphtha. Production of gas liquids and the capacities of these facilities have been included with the refineries, although little "refining" actually takes place.

As noted above, definition of the amount of naphtha being used to produce the current demand for paraxylene, orthoxylene, metaxylene, ethylbenzene (to the extent that EB is produced via this route) and solvents begins with the definition of demand for the products in each of the ten regions. Current imports and exports of mixed xylenes were also estimated. A small portion of xylenes is recovered from pyrolysis gasoline sourced from ethylene units. This was estimated based on ethylene production in each of the regions and the feeds being used. Given these elements and the configuration of production facilities within the regions, we then used an iterative simulation of a paraxylene production facility to determine the amount of naphtha consumed.

Future naphtha demand for aromatics depends on the technology section. We have therefore constructed two extreme cases: the maximum and minimum reforming cases to bracket future naphtha requirements.

Xylenes Supply from Reforming

Overall naphtha supply/demand was undertaken on a regional basis. When we turned to definition of xylenes supply, we decided that a more "micro" approach was required. To provide a detailed analysis of the current and potential sources of mixed xylenes from reformers, we developed a procedure to simulate the charge, yield, and yield quality for reformers on a refinery-by-refinery basis. Details regarding size and capabilities of reformers (pressure, severity capability, etc) were obtained from various public and private sources. This allowed us to estimate the volume of mixed xylenes produced from the reformers and the volume of mixed xylenes recovered from these reformers. We then can determine the amount of xylenes recovered for petrochemical and solvents uses, and the amount of reformer produced xylenes currently used in gasoline blending.

Since the predominant disposition of reformer xylenes is still as part of a gasoline blendstock, we have also included in our simulation an estimate of other refinery components used in gasoline blending. This allows us to estimate the volume and quality of the gasoline pool, and to assess the impact of removing additional xylenes from the gasoline pool. To some degree, this approach overlaps the more macro approach used to simulate refining regions. Although the starting points for the two analyses are completely different, key parameters such as octane, the composition of gasoline and other variables were found to be very similar.

Economics

As is the case for our supply/demand analysis, our economic analysis begins with the refinery. Refinery margins, within reasonable limits, are not a strong function of crude. We have therefore assumed that crude (WTI) will retreat from its current astronomical levels to $25.00 per barrel over the period. At any given time, the price of paraxylene is almost completely independent of crude price. We recognize, however, that the cost of paraxylene production, and more specifically the cost of naphtha, are highly tied to crude. For subscribers who would like to examine costs under another crude scenario, we suggest that naphtha price changes by about $1.07 per barrel for every dollar per barrel change in the price of WTI. This relationship is based on the regression of annual data over 20 years.

From our crude forecast and our evaluation of supply/demand balances, we have derived a margin forecast. The forecast was done using the US Gulf Coast as a basis, then adjusted to the world's major refining centres based on historical differentials and transportation economics. The crude and margin forecast "drives" gasoline price and octane value, which sets the blend value in gasoline in each of the refining centres.

The cost for producing paraxylene depends not only on the price of naphtha, but also on value of the many by-products. By-product values where set consistent with the refined product forecast or, as in the case of benzene as an example, based on separate supply/demand balances and production economics.

An economic analysis for producing paraxylene via any route depends not only on product prices, but also on yields and operating costs for the various processes involved. Reformer yields and operating costs were based on in-house data and our own reformer kinetic model. Yields and costs for the other processes (extraction, xylene isomerization, etc) were based on published information and discussions with licensors.

By establishing refined products pricing and ultimately estimates of paraxylene production costs, we were able to construct typical cost curves for region-technology combinations which were then used to drive the paraxylene supply side of the analysis. Paraxylene demand forecasts are based upon the major drivers of fibre and PET, with Asia (specifically China) forecast to be increasingly dominant in the large-scale production of polyester fibres. This shift in demand is clearly seen in the long-term demand forecasts for PTA and hence paraxylene. Once basic demand and production economics were identified, patterns of investment were considered and consequently paraxylene trade patterns were forecast. The price/margin forecasts for paraxylene were based upon our assessment of the nature and scale of investments and our opinions concerning likely commercial behaviour in the future.