

NexantThinking™

Special Reports

**China's Shale Gas Revolution-
Outlook and Opportunities for
Petrochemicals**

Brochure
September 2015



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China's Shale Gas Revolution- Outlook and Opportunities for Petrochemicals

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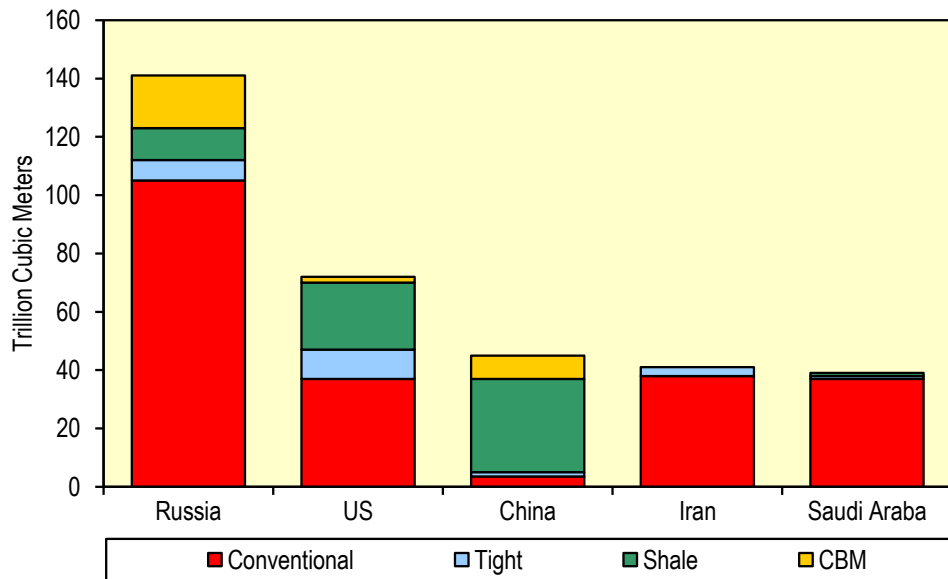
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1.1 CHINA SHALE GAS – ENERGY REVOLUTION OR EVOLUTION

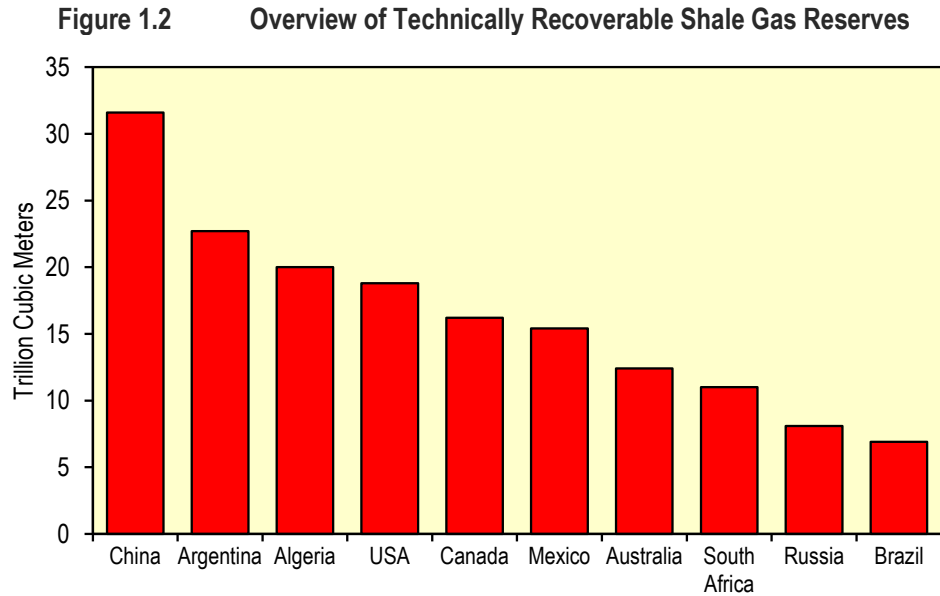
The evolving shale gas boom in the United States looks set to be rivalled by China, which sits on the world’s largest shale reserves. China’s energy market continues to develop at a rapid pace due to its vast natural resource base. However, today the focus is shifting from conventional type sources such as coal to nonconventional resources that include shale gas and coal based methane (CBM). Although in an early development phase, China’s shale gas production targets (set by the government) look set to be smashed in 2015 at between 6 to 10 billion cubic meters per annum. Furthermore investment momentum is building from both domestic and foreign entities. China is now targeting to increase domestic production levels up to 60 to 80 billion cubic meters by 2020. The emerging shale gas revolution in China is set follow the U.S. example and create a number of opportunities in the petrochemical sector and potentially change the current global landscape.

Figure 1.1 Estimate of Recoverable Natural Gas Reserves



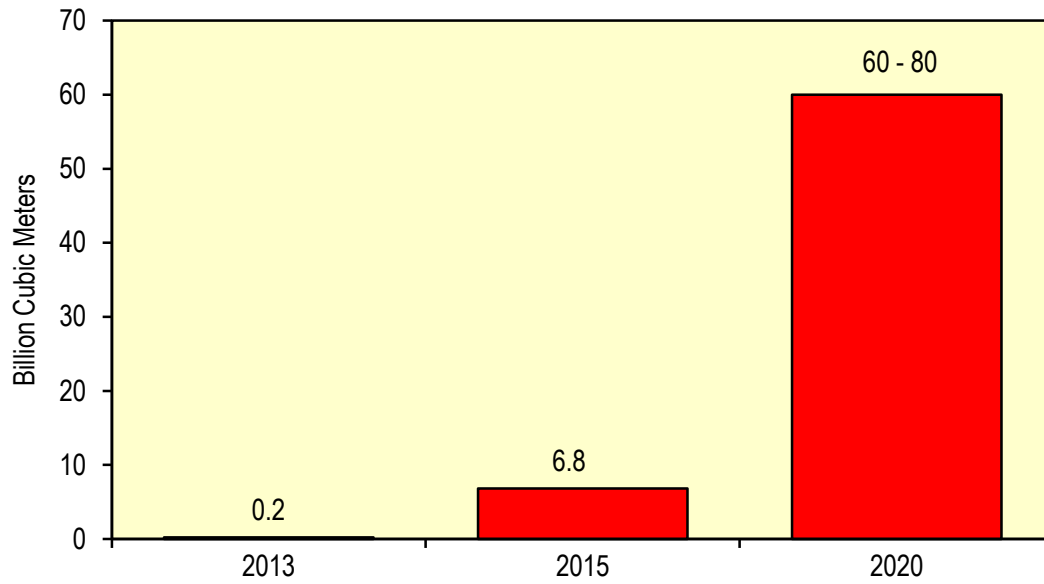
China’s government has emphasized the importance of domestic shale gas as a major initiative to improve domestic energy security. Shale gas is part of the country’s energy strategy, outlined in the state “Twelfth 5-Year” energy development plan. To date much of the development has been controlled by China’s national oil companies, CNPC, Sinopec and CNOOC. However policies are being developed, covering pricing mechanisms, special funds and exploration rights. These policies are specifically designed to promote investment from commercial entities to speed up the overall development process.

China’s total shale gas resources, as shown in Figure 1.1, are estimated at almost double that of the United States at 32 trillion cubic meters.



Nexant released a new multi-client study that provides a detailed analysis of China's Shale gas developments and highlights the potential outlook and opportunities for China's petrochemicals sector. This special report includes:

- Assessment of current and developing shale gas resources in China
- Review of existing and new gas infrastructure, covering pipelines, gas processing and NGL fractionation
- Discussion around gas quality and potential petrochemical feedstocks including ethane and propane
- Review potential petrochemical projects considering feedstock cost & availability, location and capacity development
- Discussion around global petrochemical competitiveness and possible shifts in regional trade patterns

Figure 1.3 Outlook for Shale Gas Production in China

Nexant's study provides a comprehensive analysis of China's evolving shale gas sector covering details on key players active across the value chain from exploration, production, processing, delivery, and marketing. The study includes gas production and reserve estimates covering the period 2008-2028. Petrochemical landscape developments review impact on major value chains focusing on the ethylene and propylene derivatives.

1.2 OVERVIEW OF MAJOR SHALE-GAS BASINS

China's total shale gas resource is estimated at approximately 100 trillion cubic meters (tcm). Based on current technology, approximately 25 tcm of shale gas is estimated as recoverable. This compares to the United States which has around 14 trillion cubic meters of technically recoverable gas from its shale formations. However this estimate could be higher at up to 35 tcm as advancements in deep shale drilling technology are progressing. Primary investigation into China's shale reserves, and resource mapping, started in early 2000 followed by actual resource exploitation from 2005 onwards. Early developments are concentrated on three giant basins: the Tarim Basin in the northwest, the Ordos Basin in north central China and the Sichuan Basin in the south-west. The domestic shale gas industry faces a number of challenges that include:

- **Depth of resource.** Shale reserve depths are deeper versus the United States and are in the range of 8 000-21 000. Deeper resources are stretching the limits of currently available fracking technologies.
- **Infrastructure limitations.** There is a need for significant infrastructure investments to facilitate access and monetization of China's shale resources. These include new gas pipelines, gas processing facilities and NGL fractionation plants.
- **Water shortages.** Availability of water, needed for the fracking process, is variable at different basins. Provisions to overcome water shortages at key fracking locations will be necessary.

These challenges will ultimately determine the speed of progression, price of the gas and attractiveness of China's shale gas opportunity.

Figure 1.4 Locations of Major Shale Gas Basins in China



1.3 POTENTIAL OPPORTUNITIES IN PETROCHEMICALS

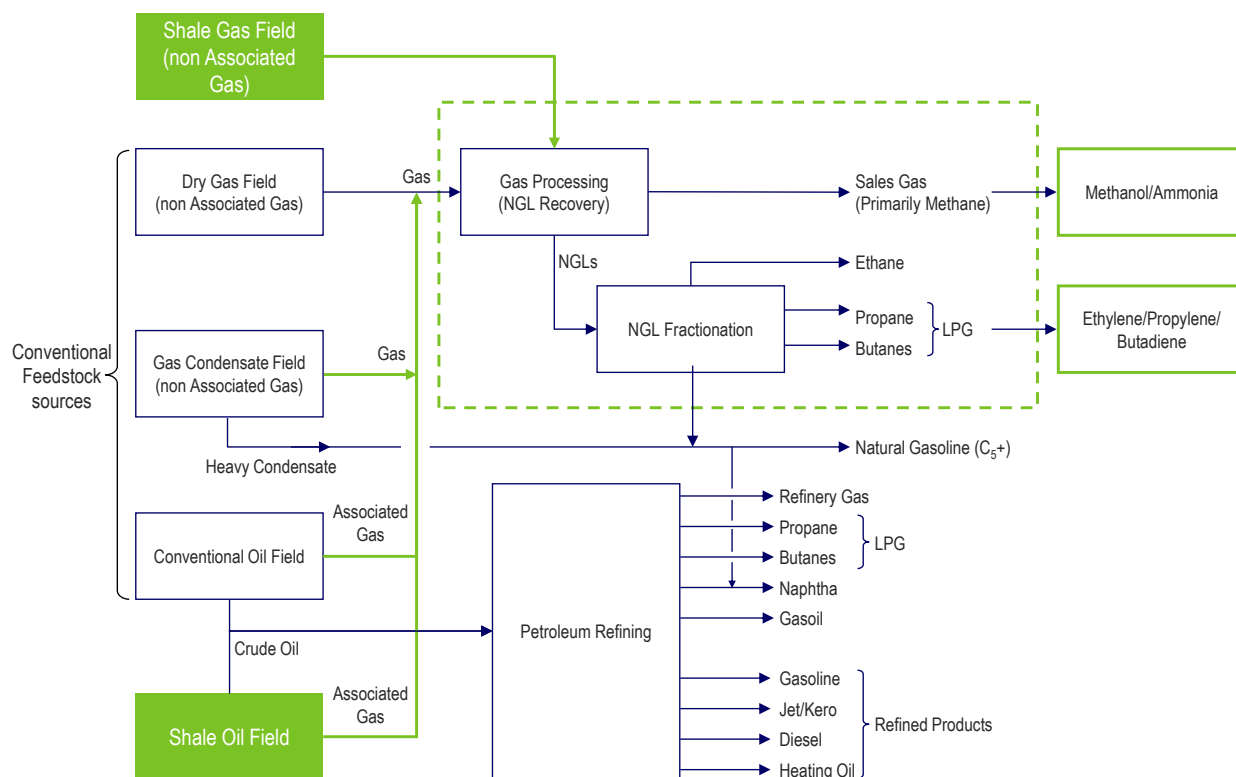
China's petrochemical industry has grown at a rapid pace over the last decade, however the market still relies heavily on imports for many chemical and polymer products. China has successfully developed a coal based chemical industry, initially focused on ammonia and methanol. The methanol sector is expanding rapidly into the production of olefins via CTO/MTO technology. Additionally, steady progress has been made in building up the country's domestic refining sector and this has led to downstream investments in naphtha cracking complexes.

The development of shale gas in China presents significant growth opportunities for the domestic petrochemical market. These opportunities include:

- Gas to methanol and methanol derivatives including methanol to olefins
- Gas to ammonia and urea
- Ethane for ethylene production
- Propane for on-purpose propylene production
- Butanes for on-purpose butadiene production

Shale resources are expected to result in increased availability of ethane and other natural gas liquids (such as propane, butane and condensates) therefore increasing the availability of petrochemical feedstocks. Furthermore increased gas supply in the Chinese domestic market is expected to result in lower feedstock pricing and increased petrochemical production competitiveness. Ultimately China's shale gas phenomenon has the potential to change the current global petrochemical landscape

Figure 1.5 Overview of Major Petrochemical Feedstocks



1.4 HOW IS NEXANT QUALIFIED TO DO THIS STUDY?

Nexant is highly and uniquely qualified to perform this study by virtue of:

- Over 50 years of experience advising the managements of the energy and chemical industries and related sectors in providing technology development, economic, market, and business strategy analysis.
- Expertise in gas exploration, gas transportation, gas processing, gas to chemicals, petrochemical market dynamics, and other relevant subjects.
- Expertise in the olefin sector covering, technology comparison, cost competitiveness and market dynamics.
- Offices in all the major markets in the Americas, Europe, the Middle East, India, South-East Asia, and China.
- A large library of relevant recent single client and multi-client work, with databases to support this.

1.5 WHO SHOULD SUBSCRIBE?

This study is essential to diverse organizations that are stakeholders in the energy and petrochemicals value chain, including:

- Private sector organizations with a stake in oil, gas and petrochemicals value chain including:
 - Energy companies, petroleum refiners, conventional fuel producers or marketers.
 - Olefin and olefin derivative producers and consumers
 - Developers of or investors in the energy sector
 - Organizations active in gas exploration, transportation and markets
- Government bodies doing research in relevant areas
- Any companies exposed to energy, gas, refining and petrochemicals

2.1 OBJECTIVE

The objective of this study is to analyze the emerging opportunity for shale gas in China and specifically assess the possible impact on the domestic and international petrochemical markets.

2.2 SCOPE AND REPORT STRUCTURE

Nexant report is organized into five major chapters as follows:

2.2.1 Review and Analysis of China Shale Gas

The report covers a detailed review of China shale gas sector looking at current and forecasted developments. The scope includes analysis of the major shale basins, reserve and production, estimates. Review of China's key government policies and plans and review of major stake holders including energy companies active within the domestic shale gas sector are included in the report.

2.2.2 Review and Analysis of China Gas Infrastructure

Focus is on current and developing gas infrastructure covering major pipeline projects, gas processing, and gas fractionation projects.

2.2.3 Review and Analysis of China Gas and NGL Markets

The report will review shale gas quality and specifications by major shale gas play and review the potential for ethane and other NGL production over the forecast period over different scenarios. The analysis will include a review of possible price setting mechanism and ethane/NGL valuations.

2.2.4 Review and Analysis of China's Gas Based Chemical Sector

Focus is on possible opportunities for domestic petrochemical development. This includes prospects for natural gas chemicals (methanol and ammonia) and outlook for olefins. The report focuses on ethane availability for ethylene production and propane for ethylene/propylene production. The analysis includes a breakdown of China's olefin business by feedstock and cost.

2.2.5 Implications for Global Petrochemical Markets

Analysis reviews possible changes to China's petrochemical market covering new capacity additions, impact on petrochemical cost competitiveness and outlook for trade. The study includes analysis on the implications for the global petrochemical sector and provides opinion on the changing petrochemical landscape that may result from China's shale gas developments.

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3.1 GENERAL

Nexant utilizes its unique consulting skills and combination of global, regional, and industry sector experience to bring readers real insight into the supply availability and pricing of shale gas as a feedstock for chemicals. The basic approach consists of:

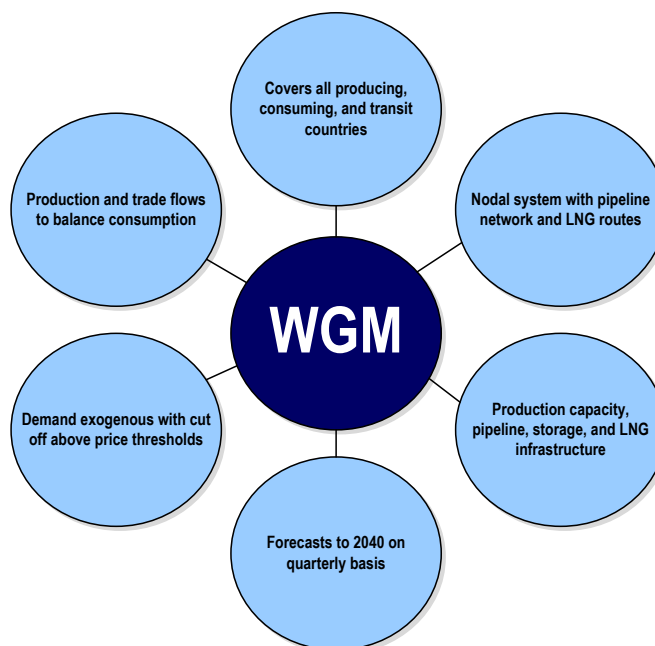
- Drawing on Nexant's in-house database on the specific gas markets in terms of understanding supply, demand, infrastructure, pricing and the regulatory framework.
- Utilizing the *World Gas Model* to generate prospective supply – demand balances and pricing projections under different scenarios.
- Discussions with Nexant's key contacts in the specific countries to add further insight to each gas market.
- Additional research from the public domain.
- Utilizing Nexant's economic and financial models and expertise to consider the comparative economics in each country for each product for the relevant end-use markets.

3.2 GAS MARKET ANALYSIS

The market analysis for this report is prepared drawing on Nexant's recent studies, both multi-client and single client, and the *World Gas Model* and its extensive database.

Nexant's World Gas Model is available for clients to use under license on their own systems and is also used by Nexant's Global Gas experts to support our consultancy assignments and multi-client studies and reports. Key elements of the model are shown in Figure 4.1. Nexant has used this modeling system to provide the underlying foundation for the market and pricing assessments presented in this report.

Figure 3.1 World Gas Model



WGM uses a powerful optimizer program, in conjunction with Microsoft Excel, which allows all inputs and outputs to be analyzed by users and linked to other in-house systems. The model projects global, regional, and national gas supply demand balances, international gas trade by pipeline and LNG and both contracted and spot prices. Spot prices are estimated with reference to the cost of supply, competing

prices, and the “tightness” of the market. The model currently has an outlook period to 2040 and the model is balanced on a quarterly basis.

3.2.1 Global Coverage

The model considers every country in the world which either consumes or produces natural gas. Large countries including the United States, Canada, Russia, China, Australia, Malaysia, and Indonesia are further segmented by regions. The focus is on the growing international trade of natural gas by cross-border pipeline and as LNG.

The model currently includes over 130 countries with space to add new countries as needed.

3.2.2 Gas Demand

Gas demand projections are exogenous allowing users to overwrite Nexant assumptions with in-house projections and scenarios.

The model itself will adjust demand levels using a Demand Side Response mechanism which simulates switching to alternative fuels arising from high cost of gas supply or infrastructure bottlenecks.

3.2.3 Infrastructure and Supply

The model includes detailed data on the gas infrastructure and supply needed to support international trade, including production fields and basins, pipelines, LNG liquefaction and regasification terminals and storage facilities, together with associated costs.

Project start and end dates are varied allowing clients to develop alternative scenarios of specific interest.

3.2.4 Gas Contracts

The model includes information on long-term contracts on gas supply by both cross-border gas pipeline and LNG. Volumes are controlled within the range set by Annual Contract Quantity and take-or-pay volumes. Gas prices are simulated in relation to a basket of up to five escalators including oil prices and gas spot prices.

3.2.5 Cost Data

Cost data is included for all facilities in the model including production, pipelines, liquefaction, and regasification terminals, storage facilities, and LNG shipping. Capital costs for production and infrastructure are represented as unit costs (per MMBtu or per thousand cubic meters - mcm) on a Long Run Marginal Cost (LRMC) basis. Shipping costs are built up from shipping distances and assumed day rates and fuel costs.

3.2.6 Gas Prices

Contract prices are calculated within the model based on assumed oil and oil product prices in Europe and Asia. Spot prices are projected within a range determined by the cost of supply and price of alternative fuels. The position within this range depends on how tight the market is at any time.

3.3 MARKET ANALYSIS: METHODOLOGY

Background

Market analysis developed by Nexant is compiled from external data – based on public domain information and industry interviews – by a comprehensive database engine that simulates global industry market dynamics, techno-economics and profitability for all key petrochemicals. This state-of-the-art Global Industry Simulator (GIS) builds on reliable data and proven models.

Already the industry leader in terms of its quality business planning consultancy (including profitability forecasting), the GIS has enabled Nexant to take a further leap forward. It has replaced over 10,000 spread-sheets and 25 databases and ensures a rigorous convergence on consistent sets of projections that satisfy all the influencing business rules. This is unique in chemical industry consulting, providing greater confidence in consistency. An overview of the GIS is shown in Figure 4.1 and general layout of data flow is shown in Figure 4.2.

The principal factors considered for Nexant simulations are as follows:

- Primary energy pricing (crude oil and natural gas prices, petrochemical feedstocks, power costs).
- Economic growth (GDP growth projections; industrial, agriculture, automotive, construction, consumer spending and other sector projections; population growth).
- Currency exchange rate projections.
- Inflation projections – capital, wage and general inflation.
- Petrochemical asset development profiles (both planned and expected in the next four years and speculative addition/shutdown thereafter).

Nexant has a long history of working in the global petrochemical markets and has access to an extensive network of contacts throughout the different regions. Additionally, Nexant conducts annual field research across all major chemicals and polymers as part of its NexantThinking™ multi-client reports and has an impressive contact base of suppliers and consumers within the chemical sector.

Figure 3.2 Global Industry Simulator

Powered by a State of the art industry simulator that builds on reliable data and proven models

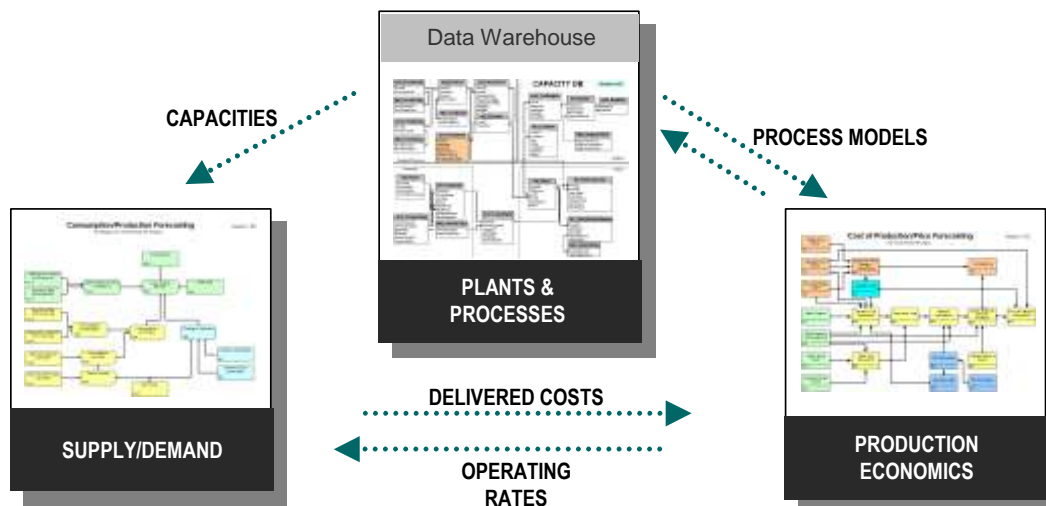
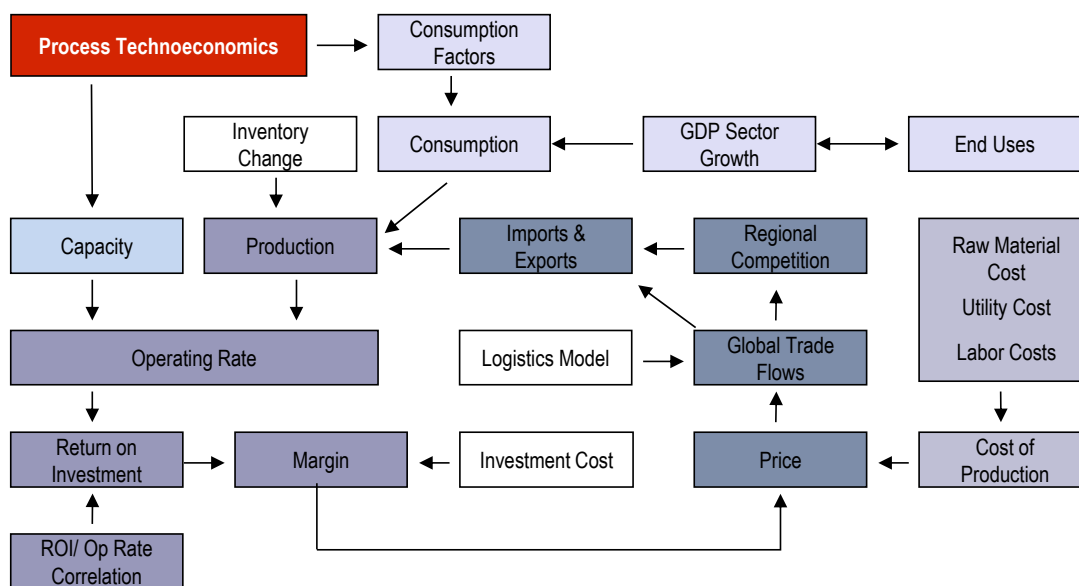


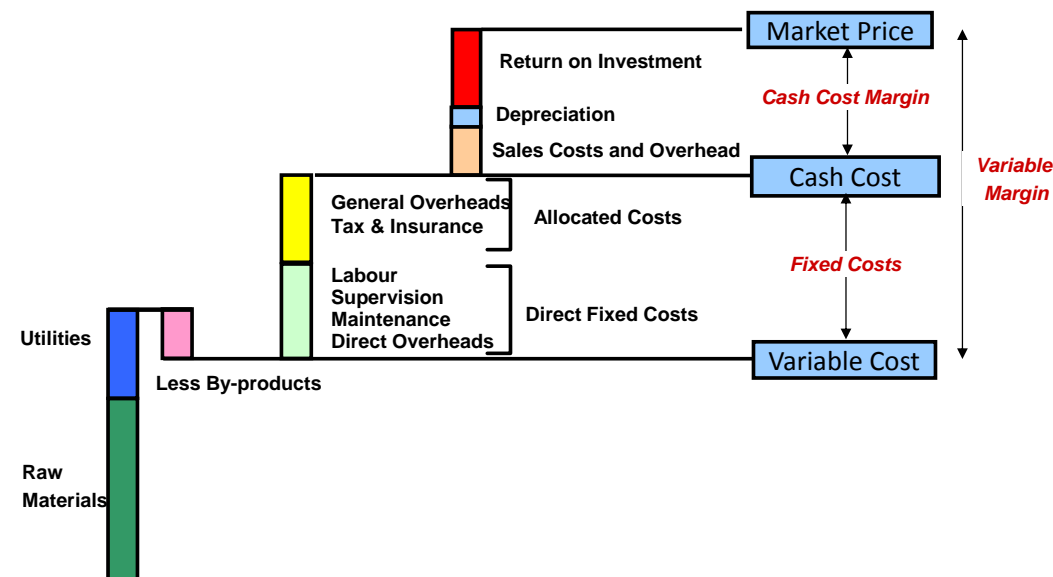
Figure 3.3 Data Flow within the Global Industry Simulator



3.4 PRICE FORECASTING METHODOLOGY

The primary drivers of price for most petrochemical products are a combination of the cost of raw materials and the supply/demand balance of the market. These two drivers combine to derive the price via the fundamental relationship of cost plus margin. The key components of a market price, namely the production cost and the margin, are presented in Figure 3.4.

Figure 3.4 Components of a Market Price
(relative sizes of bars are for illustrative purposes only)



The variable cost of production is determined from raw material costs and the cost of utilities less relevant credits for co-products. To this are added the fixed costs associated with running the plant, consisting of operating labor, maintenance, general plant and works overheads, and tax and insurance, to give the cash cost of production. Cash costs for the forecast period are projected based upon raw material costs

(usually strongly influenced by the prevailing crude oil price) and the other associated costs of production, making assumptions about the reduction of costs over time due to experience curve effects. The margin is determined from the return on investment (ROI) forecast that, in turn, is derived from an analysis of the historical relationship of profitability with average industry operating rate. The combination, cost plus margin, making allowance where appropriate for freight and packaging, produces the price.

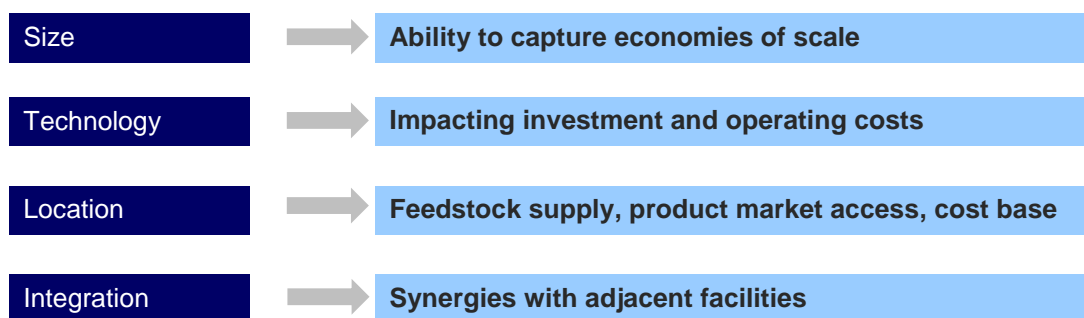
Secondary influences on the price forecasts may include:

- Forecast prices in other regions.
- Relationship to other petrochemical products (e.g. inter-polymer relationships).
- Profitability of upstream and downstream processes.

3.5 COMPETITIVE ANALYSIS

Nexant's analysis of production competitiveness uses a semi quantitative assessment to measure the impact on underlying margin competitiveness of any refinery or chemical project versus its key competitors

Petrochemicals competitiveness typically addresses a number of similar well proven, but simple criteria:



The impact of these factors on overall Project competitiveness is considered both qualitatively and quantitatively by consideration of production cost and delivered cost competitiveness of production from the Project to key target markets versus other key competitors.

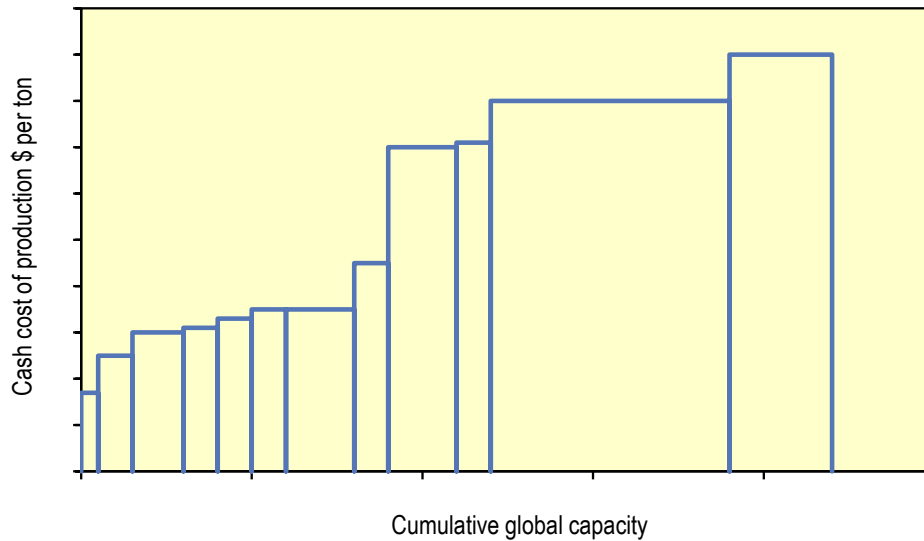
Nexant's approach to determining delivered cost competitiveness includes a number of elements as shown in Figure 4.4.

- The variable cost of production includes the costs of raw materials – feedstocks plus catalysts and chemicals – and utilities at cash cost or purchase cost, with a credit for co-products.
- The cash cost of production includes:
 - Salaries of operating staff plus associated on-costs such as holiday cover, social insurance, fringe benefits etc.
 - Maintenance costs including materials and labour, with periodic maintenance costs such as two or three year shutdowns averaged over the period; maintenance costs are usually calculated as a percentage of process plant capital cost.
 - Synthesis of specific non confidential site-specific industry knowledge.
 - The allocated fixed costs are the site charges, which are necessary for production but which are not directly associated with the operation of the specified process plant. They include packing and warehousing, storage and workshops, site laboratories, safety and environment, security, site management, and on-site amenities for the workers. Insurance of the fixed assets is also counted under allocated fixed costs.

As defined by Nexant for its analyses of production costs and its price forecasting, the cash cost does not include corporate overheads such as general marketing, company administration, and R&D. Nor does it include working capital.

Nexant uses its cost competitiveness modelling approach to develop simplified industry curves which are representative of global and regional production. An example is provided in Figure 4.5.

Figure 3.5 Example Cost Curve Analysis



4.1 GENERAL

Nexant uses multidisciplinary project teams drawn from the ranks of our international staff of engineers, chemists, economists and financial professionals, and from other Nexant groups to respond to the requirements of each assignment. Most of the consulting staff possesses credentials in both scientific and commercial disciplines plus substantial industrial experience. The collective talents of our staff are strategically located and closely linked throughout the world, resulting in valuable insights gained through a variety of perspectives.

Nexant is an international consultancy and is dedicated to assisting businesses within the global energy, chemical, plastics, and process industries by providing incisive, objective, results-oriented management consulting. Over four decades of significant activity translates into an effective base of knowledge and resources for addressing the complex dynamics of specialized marketplaces. By assisting companies in developing and reviewing their business strategies, in planning and implementing new projects and products, diversification and divestiture endeavors and other management initiatives, Nexant helps clients increase the value of their businesses. Additionally, we advise financial firms, vendors, utilities, government agencies and others interested in issues and trends affecting industry segments and individual companies.

The Nexant Group was formed as an independent global consulting company in 2000, combining a number of companies that had a long history of providing consultancy services to the chemical and refining-related industries. Nexant’s experience covers all aspects of project development relating to major refinery, petrochemical, and polymer investments, ranging from grassroots plants to revamps of existing process units. Nexant’s key offices serving the petrochemical and downstream oil sectors are located in New York, Houston, London, Bangkok, and Bahrain, and locations for other offices are shown in Figure 4.1.

Figure 4.1 Nexant Office Locations



From major multinationals to locally based firms and governmental entities, our clients look to us for expert judgment in solving compelling business and technical problems and in making critical decisions.

Nexant's clients include most of the world's leading oil and chemical companies, financial institutions, and many national and regional governments. Nexant, Inc. is active in most of the industrialized countries of the world, as well as in most of the developing areas including the Middle East, Africa, and East and South-East Asia.

Major annual subscription programs are:

- Process Evaluation/Research Planning (PERP)
- Biorenewable Insights
- Petroleum & Petrochemical Economics (PPE) – United States, Western Europe, and Asia
- Polyolefin Planning Service (POPS)

The PERP program covers technology, commercial trends, and economics applicable to the chemical industry. The program has more than 40 subscribers, including most of the major international chemical companies. Many of the processes to be analyzed in this multi-client study have been assessed in the PERP program.

The Biorenewable Insights program covers technology, capacity trends, and economics applicable to the biorenewable industry. Many of the processes to be analyzed in this multi-client study have been assessed in the Biorenewable Insights program.

The PPE program provides historic and forecast analysis of the profitability, competitive position, and supply/demand trends of the global petroleum and petrochemical industry. The program includes capacity listings and analysis, global supply, demand and trade balances, profitability, competitiveness, and price analysis and projections for all the major petrochemical value chains. The PPE program is supported by an internet-based planning and forecasting tool that provides online access to the database behind the reports of the PPE program.

The POPS program provides reports on the global polyethylene and polypropylene industry. It is recognized globally as the benchmark source for detailed information and analysis on current commercial, technical, and economic developments in the polyolefins industry. Coverage includes: capacity listing and analysis, detailed consumption, supply/demand, trade, operating rates, price forecasts, technological developments, new products, inter-material substitution, and regional competitiveness.

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