Methanol to Aromatics – Global Impact of a New Technology

Brochure

December 2015

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# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Introduction .................................................................</td>
</tr>
<tr>
<td>1.1</td>
<td>INTRODUCTION AND OBJECTIVES ...............................................</td>
</tr>
<tr>
<td>1.2</td>
<td>BACKGROUND ........................................................................</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Scope of Work ......................................................................</td>
</tr>
<tr>
<td>2.1</td>
<td>REPORT OVERVIEW .................................................................</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Table of Contents ..................................................................</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Approach .............................................................................</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Qualifications ......................................................................</td>
</tr>
<tr>
<td>5.1</td>
<td>GENERAL .............................................................................</td>
</tr>
<tr>
<td>5.2</td>
<td>SUMMARY OF PROJECTS RELATED TO COAL-TO-CHEMICALS .............</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Contact Information .............................................................</td>
</tr>
<tr>
<td>6.1</td>
<td>CONTACT DETAILS ..................................................................</td>
</tr>
</tbody>
</table>
Section 1
Introduction

1.1 INTRODUCTION AND OBJECTIVES

China’s consumption of benzene and para-xylene is set to vastly outstrip the growth in supply from conventional sources. New export-oriented aromatics capacity is being built in regions such as the Middle East and South Korea to service the expected demand growth for imports in China. A new technology which efficiently converts methanol to aromatics has however emerged in China, and is creating a wave of investment that appears set to transform global trade outlook for aromatics. The production base for methanol-to-aromatics in China will be largely coal-based, and will effectively offset imports of crude oil-based hydrocarbons. The new methanol route to aromatics could also provide a profitable platform for export development in gas-rich regions.

The comparative economics of the new syngas process versus conventional naphtha-based production throws into question the current surge in export-oriented naphtha-based developments in the Middle East and East Asia, which is predicated on growing demand for imports into China. Regional differences in the availability of gas and naphtha will dictate how the different processes develop around the world.

This report defines the commercial impact of this transformational development in the global aromatics industry, and will provide essential guidance to:
- Existing producers of aromatics in all regions
- Sponsors of new export-based aromatics investments around the world
- Refiners with exposure to naphtha sales
- Resource owners seeking to add value to crude oil and refined products
- Gas and methanol producers around the world
- Strategic consumers of benzene and para-xylene
- Technology suppliers in the conventional aromatics area

1.2 BACKGROUND

China’s dependence on imported crude oil and its derivatives has become an issue of national concern, and the prevailing high oil prices have further encouraged alternative chemical production routes which can be based upon China’s abundant coal reserves rather than imported crude oil or refined products such as naphtha. Despite the fall in crude oil and polymer prices, MTO operators continue to post strong results. The growing oversupply of coal in China has led to enforced production cutbacks, leading coal producers to pursue new outlets for coal. Developments of coal-based vinyls and methanol have already had a transformative on the global supply/demand balance for these product groups. Chinese methanol capacity has already soared to 65 million tons per year, over half of global capacity. Coal gasification for products such as methanol has been increasingly popular, as it provides a means of monetizing low grade coals such as lignite which have minimal alternative value, as well as conventional thermal coals.

Coal-based synthesis gas (“syngas”) has been replaced by more competitive natural gas-based production in most regions, but the lack of natural gas and abundance of coal in China favors the coal route. High capital costs and environmental emissions associated with coal gasification were the principal reasons for the decline in coal gasification outside China.

Technologies such as Fischer Tropsch for the production of straight chain hydrocarbons from syngas have existed for some time, and have been commercialized on a large scale in recent years in gas rich regions such as Qatar. Synthetic fuels produced by this means are an alternative to methanol or LNG for resource owners seeking to monetize stranded gas. Mobil operated a methanol-based synthetic gasoline plant in
New Zealand, which utilized the intermediate DME. This plant however became uneconomical due to the higher alternative market value for the methanol, and the site subsequently became a major methanol exporter for some time under the ownership of Methanex.

The coal-based chemicals industry in China has expanded at an astonishing rate. The developments provide opportunities for economic development, employment and tax revenue generation in the coal-rich inland regions. This corresponds directly with the goals of the government’s West Development Plan. Local coal-based chemicals and polymers also offset imports of polymers and petrochemical feedstocks, which corresponds with the state objectives on reducing the dependence on imports of strategic raw materials. The production of high-value petrochemicals and polymers also provides a means of monetizing coal reserves which are otherwise difficult to exploit due to their low value and distance from consumers. These factors combine to form a potent incentive for investment and the volume of capacity which has been developed defies the conventional logic driving the chemicals investment cycle. Figure 1.1 illustrates the development of the PVC industry in China, which has been propelled by coal/acetylene based VCM. China has moved from being the world’s leading importer of PVC to a situation of massive structural oversupply, and China’s capacity based is now 46 percent of the total global industry. It is worthy of note that the margins on coal-based vinyls have frequently been challenging over this period of expansion, and also that heavy capacity addition is still ongoing.

![Figure 1.1 China PVC Supply/Demand](image)

Figure 1.2 illustrates the pace of development of the methanol industry in China, which is almost exclusively based on coal. As with PVC, methanol capacity is now much greater than demand. Some of the new mega-methanol plants were developed with DME as a planned end-use, although the market for DME did not eventually develop as expected. Some of the existing methanol capacity will be dedicated to the rapidly expanding methanol-based olefins developments, but there remain several million tons of idle new capacity which could in theory serve new methanol-based aromatics developments.
Figure 1.2  China Methanol Supply/Demand

The rate at which coal-based capacity for vinyls and methanol has expanded in China therefore suggests a massive potential impact on the aromatics market. The rate of development of MTA already looks explosive, with three pilot plants demonstrated over 2013, and commercial scale projects now under development.

Conventional naphtha-based aromatics production has not historically experienced competition from any alternative processes, but will now be subject to competition from natural gas based production. Investors in export-based aromatics production will now need to consider whether or not the naphtha route will offer an acceptable investment opportunity in the face of competition from coal-based production in China, and methanol-based aromatics in other regions.

This study gives subscribers a solid grasp of the volume of coal-to-aromatics capacity likely to enter the market over the coming years, and the cost position relative to naphtha within defined crude oil pricing scenarios. The study also analyzes the competitiveness of MTA production in gas rich regions, as an alternative to naphtha-based developments. In consideration of the competitive dynamics in the industry, the report examines the likely impact on the development of global trade patterns for benzene and para-xylene.

The study includes a description and evaluation of the new Chinese technology, and a cost of production analysis for coal-based production, on a mine-mouth basis, as compared to the production cost of the same product via petrochemical routes. The two sets of economics are contrasted on a delivered “Coastal China” basis.

This prospectus describes Nexant’s Methanol-to-Aromatics multi-client study, provides the report Table of Contents, the methodology used, and Nexant’s qualifications to perform such a study. The study was published in the fourth quarter of 2015.
Section 2

Scope of Work

2.1 REPORT OVERVIEW

2.1.1 Summary

The report provides detailed analysis of the new MTA (methanol-to-aromatics) technologies being deployed in China, and provides cost of production estimates for integrated coalfield methanol and MTA production as well as economics for MTA in a coastal China location. The report also compares the competitiveness of MTA against archetypal conventional suppliers in East Asia, Eastern Europe, the Middle East and the United States.

Coal pricing has become as volatile as that of crude oil, and the report therefore provides a detailed background on the status of the coal industry in China, the coal types under consideration for this analysis, and defines a likely price spread for coal which in which the competitiveness of MTA can be assessed under different crude oil price scenarios.

Considering the potential for development based on the competitiveness of the process, the report defines a scenario by which the industry is most likely to develop, and assesses the impact on other producing regions around the world.

Methanol-to-aromatics is also set to significantly reduce naphtha demand into conventional reformer-based aromatics production, and the report also considers this impact and provides a view on the likely shortfall in naphtha consumption relative to Nexant’s base case forecast.

The process development is diverging into fluidized bed and fixed bed reactor schemes, and the report provides process description and cost analysis for both. The report also details the origins and evolution of the technology.

2.1.1.2 Comparative Economics versus Naphtha

The study provides a Delivered Coastal China cost estimate for coal/methanol based MTA, using mine-mouth coal economics. The analysis further considers the issue of coal transfer pricing, where integrated producers can transfer coal at its production cost which is frequently well under half of the market price. These cost positions are ranked against the current main supply options, which are integrated naphtha reformer/aromatics complexes in:

- Eastern Europe
- South Korea
- United States
- Middle East

The MTA cost includes domestic transports costs from inland provinces, and the import costs include freight, handling costs, and duties where applicable.

2.1.1.3 Year

Cost of production economics are prepared based on a Q2 2015 basis utilizing raw material and other pricing from Nexant’s historical pricing databases and public domain resources. The analysis correctly positions coal-based economics in the lower oil price environment.
# Section 3

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Executive Summary</td>
<td>1-1</td>
</tr>
<tr>
<td>1.1</td>
<td>MARKET SITUATION</td>
<td>1-1</td>
</tr>
<tr>
<td>1.2</td>
<td>CHINA COAL INDUSTRY SITUATION</td>
<td>1-1</td>
</tr>
<tr>
<td>1.3</td>
<td>MTA DEVELOPMENTS</td>
<td>1-1</td>
</tr>
<tr>
<td>1.4</td>
<td>PROCESS OUTLINE</td>
<td>1-2</td>
</tr>
<tr>
<td>1.5</td>
<td>COMPETITIVENESS</td>
<td>1-2</td>
</tr>
<tr>
<td>1.6</td>
<td>COMPETITIVE SITUATION OF METHANOL-TO-AROMATICS</td>
<td>1-3</td>
</tr>
<tr>
<td>1.7</td>
<td>OUTLOOK</td>
<td>1-5</td>
</tr>
<tr>
<td>1.8</td>
<td>CONCLUSIONS</td>
<td>1-5</td>
</tr>
<tr>
<td>2</td>
<td>Introduction</td>
<td>2-1</td>
</tr>
<tr>
<td>2.1</td>
<td>OVERVIEW</td>
<td>2-1</td>
</tr>
<tr>
<td>2.2</td>
<td>THE AROMATICS INDUSTRY</td>
<td>2-1</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Market Summary</td>
<td>2-2</td>
</tr>
<tr>
<td>2.3</td>
<td>THE METHANOL INDUSTRY</td>
<td>2-15</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Introduction</td>
<td>2-15</td>
</tr>
<tr>
<td>2.4</td>
<td>STRATEGIC DRIVERS FOR MTA</td>
<td>2-21</td>
</tr>
<tr>
<td>3</td>
<td>The Chinese Coal Industry</td>
<td>3-1</td>
</tr>
<tr>
<td>3.1</td>
<td>CURRENT SITUATION</td>
<td>3-1</td>
</tr>
<tr>
<td>3.2</td>
<td>COAL PRODUCTION COST AND PRICING</td>
<td>3-3</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Coal Quality</td>
<td>3-3</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Types of Coal</td>
<td>3-3</td>
</tr>
<tr>
<td>3.2.3</td>
<td>Location and Transport Costs</td>
<td>3-6</td>
</tr>
<tr>
<td>3.2.4</td>
<td>Coal Pricing</td>
<td>3-6</td>
</tr>
<tr>
<td>3.2.5</td>
<td>Coal Price Outlook</td>
<td>3-8</td>
</tr>
<tr>
<td>4</td>
<td>Methanol-to-Aromatics Technologies</td>
<td>4-1</td>
</tr>
<tr>
<td>4.1</td>
<td>INTRODUCTION</td>
<td>4-1</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Methanol from Coal</td>
<td>4-2</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Fluidized-Bed MTA (FMTA) Process</td>
<td>4-4</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Fixed-Bed MTA Process</td>
<td>4-6</td>
</tr>
<tr>
<td>4.2</td>
<td>ORIGINS OF METHANOL TO AROMATICS TECHNOLOGY</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.1</td>
<td>MTG Chemistry and Reaction Mechanism</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Zeolite Socony Mobil # 5 (ZSM-5) Catalyst</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Original Mobil MTG Process – Fixed Bed Process</td>
<td>4-12</td>
</tr>
<tr>
<td>4.2.4</td>
<td>URBK-Uhde-Mobil MTG Process – Fluid Bed Process</td>
<td>4-16</td>
</tr>
</tbody>
</table>

### Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Methanol-to-Aromatics Technologies</td>
<td>4-1</td>
</tr>
<tr>
<td>4.1</td>
<td>INTRODUCTION</td>
<td>4-1</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Methanol from Coal</td>
<td>4-2</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Fluidized-Bed MTA (FMTA) Process</td>
<td>4-4</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Fixed-Bed MTA Process</td>
<td>4-6</td>
</tr>
<tr>
<td>4.2</td>
<td>ORIGINS OF METHANOL TO AROMATICS TECHNOLOGY</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.1</td>
<td>MTG Chemistry and Reaction Mechanism</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Zeolite Socony Mobil # 5 (ZSM-5) Catalyst</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Original Mobil MTG Process – Fixed Bed Process</td>
<td>4-12</td>
</tr>
<tr>
<td>4.2.4</td>
<td>URBK-Uhde-Mobil MTG Process – Fluid Bed Process</td>
<td>4-16</td>
</tr>
</tbody>
</table>
5 Economics ........................................................................................................................................... 5-1
  5.1 BASIS OF ECONOMICS .................................................................................................................. 5-1
      5.1.1 Cost of Production Terminology ............................................................................................... 5-1
      5.1.2 Location Factors ....................................................................................................................... 5-2
      5.1.3 Plants Considered ...................................................................................................................... 5-2
      5.1.4 Location and Market Coverage .............................................................................................. 5-3
  5.2 FEEDSTOCK PRICES ....................................................................................................................... 5-3
      5.2.1 Naphtha Price .......................................................................................................................... 5-3
      5.2.2 Coal Price in China ................................................................................................................... 5-4
      5.2.3 Gas Prices ............................................................................................................................... 5-4
      5.2.4 Benzene Prices ......................................................................................................................... 5-5
  5.3 SHIPPING AND TARIFF COSTS ..................................................................................................... 5-6
      5.3.1 Shipping Costs .......................................................................................................................... 5-6
      5.3.2 Tariff ....................................................................................................................................... 5-6
  5.4 COST OF PRODUCTION – METHANOL TO AROMATICS .............................................................. 5-7
      5.4.1 Methanol – From Coal Syngas (Ordos, China Mine-Mouth) ...................................................... 5-7
      5.4.2 Methanol – From Coal Syngas (China Coastal) ....................................................................... 5-7
      5.4.3 MTA – Fluidized Bed, From Methanol (Ordos, China Mine-Mouth) ...................................... 5-7
      5.4.4 MTA – Fixed Bed, From Methanol (China Mine-Mouth) ......................................................... 5-11
      5.4.5 para-Xylene – Isomerization/Separation from Mixed Xylenes (Ordos Mine-mouth, Integrated Fluidized Bed MTA) ................................................................. 5-11
      5.4.6 para-Xylene – Isomerization/Separation from Mixed Xylenes (Ordos Mine-Mouth, Fixed Bed MTA) ................................................................................. 5-11
      5.4.7 MTA – Fluidized Bed, From Methanol (China Coastal) ........................................................... 5-11
      5.4.8 MTA – Fixed Bed, From Methanol (China Coastal) ................................................................. 5-11
      5.4.9 para-Xylene – Isomerization/Separation from Mixed Xylenes (Integrated Fluidized bed MTA, Coastal China) ................................................................. 5-17
      5.4.10 para-Xylene – Isomerization/Separation from Mixed Xylenes (Integrated Fixed bed MTA, Coastal China) ........................................................................ 5-17
  5.5 COST OF PRODUCTION – CONVENTIONAL NAPHTHA REFORMING ........................................ 5-17
      5.5.1 para-Xylene (China) .................................................................................................................. 5-17
      5.5.2 para-Xylene (South Korea) ....................................................................................................... 5-17
      5.5.3 para-Xylene (Middle East) ....................................................................................................... 5-22
      5.5.4 para-Xylene (United States) .................................................................................................... 5-23
      5.5.5 para-Xylene (Eastern Europe) .................................................................................................. 5-24
  5.6 SENSITIVITY TO COAL AND NAPHTHA PRICE ........................................................................ 5-27
  5.7 CONCLUSIONS ............................................................................................................................. 5-28
  5.8 PARA-XYLENE PRICE AND MARGIN OUTLOOK ......................................................................... 5-29
5.8.1 Price Basis and Value Influencing Factors ........................................... 5-29
5.8.2 Profitability Projections ........................................................................ 5-30
5.8.3 Competitive Situation of Methanol-to-Aromatics .................................. 5-31

6 Chinese MTA Developments ........................................................................ 6-1
  6.1 OVERVIEW ............................................................................................. 6-1
  6.2 MTA DEVELOPMENTS .......................................................................... 6-2
      6.2.1 Company Profiles ........................................................................... 6-2
      6.2.2 Active Projects ............................................................................... 6-2
      6.2.3 Capacity Development Outlook ...................................................... 6-3

7 Global Supply/Demand Impact....................................................................... 7-1
  7.1 OVERVIEW ............................................................................................. 7-1
      7.1.1 Regional Attractiveness of MTA ....................................................... 7-1

8 Impact on Feedstocks and Co-products .......................................................... 8-1
  8.1 OVERVIEW ............................................................................................. 8-1
  8.2 IMPACT ON FEEDSTOCK DEMAND ....................................................... 8-1
      8.2.1 Methanol ......................................................................................... 8-1
      8.2.2 Coal ............................................................................................... 8-1
      8.2.3 Naphtha ........................................................................................ 8-2
  8.3 IMPACT ON CO-PRODUCTS .................................................................. 8-3
  8.4 CONCLUSIONS ....................................................................................... 8-4

Appendix ........................................................................................................... A-1
  A Cost of Production Estimates ...................................................................... A-1
The evaluations of conventional technology are based on Nexant’s in-house and published information regarding process technology, augmented by contacts with licensors, engineering contractors and other experts in the industry. The evaluations of developing technology are based on a review of patents, public domain information, and discussions with technology development companies and engineering contractors.

Nexant uses proprietary and commercial state-of-the-art software tools to develop the technology and economic estimates. These are well established, state-of-the-art engineering tools in the chemical process industry and are used by major engineering contractors.

Nexant’s economic evaluations are designed to approximate typical regional costs of production based on capital costs that are appropriate for “factored estimates”. They do not reflect specific site issues, but are a reasonable representation of the subject countries/regions.
Section 5  Qualifications

5.1  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 5.1.

Figure 5.1  Nexant Office Locations

- Headquarters
- Main Offices
- Representative Offices
- Project Offices
- San Francisco
- White Plains
- Washington, DC
- White Plains
- London
- Frankfurt
- Bahrain
- New Delhi
- Bangkok
- Tokyo
- Shanghai
- Kuala Lumpur
- Bangkok
- Buenos Aires
- Rio de Janeiro
- La Paz
- Pretoria
- Abuja
- Pretoria
- Riyadh
- Jakarta
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 Southeast Asia.

Major annual subscription programs are:

- Process Evaluation/Research Planning (PERP)
- Petroleum & Petrochemical Economics (PPE)
- 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 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.
5.2 SUMMARY OF PROJECTS RELATED TO COAL-TO-CHEMICALS

- COAL TO CHEMICALS - Visiting and Revisiting the Future -- This report provides a solid grasp of the state of development of coal to chemicals technologies, including an update on the status of such technologies as currently practiced in China, as well as providing a snapshot analysis of the most favorable coal to chemicals economics, on a mine-mouth basis, as compared to the production cost of the same product via petrochemical routes.

- SYNTHETIC FUEL CAPITAL AND PRODUCTION COSTS -- Nexant performed this study for the U.S. Department of Energy (DOE) as input to their assessment of the costs and benefits of flexible and alternative fuel use in the U.S. transportation sector. Nexant reviewed state-of-the-art coal liquefaction technology and developed production cost estimates for producing synthetic crude and then upgrading the syncrude to a gasoline product.

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- SYNTHETIC FUEL CAPITAL AND PRODUCTION COSTS -- Nexant performed this study for the U.S. Department of Energy (DOE) as input to their assessment of the costs and benefits of flexible and alternative fuel use in the U.S. transportation sector. Nexant reviewed state-of-the-art coal liquefaction technology and developed production cost estimates for producing synthetic crude and then upgrading the syncrude to a gasoline product.

- COAL TO MEG – Technical and Strategic Evaluation -- Nexant’s technical staff in China produced an accurate technical and economic analysis of the emerging coal-to-MEG process, which was an entirely novel production scheme involving the intermediate dimethyl oxalate. The strategic evaluation covered the potential impact of the Chinese capacity development on MEG exporters in other regions.

- CHEMICALS FROM COAL AND SHALE FEEDSTOCKS -- Recognizing the eventual importance of coal and shale resources in replacing gas and petroleum, this study examined the various technologies that could be used to produce feedstocks and chemicals. Three separate potential implementation cases were treated in detail: Economic, By-product, and “National Need.” The production of synthetic fuels, olefins and aromatics and their derivatives from coal and shale were projected. A large number of patent references and flowsheets are included in the study, which also reviewed the chemical implications of synthetic fuels programs in the United States and elsewhere. There is also a section on utilization of U.S. tar sands resources.

- SYNTHESIS GAS (FUTURE SOURCES) -- This report reviewed the technology for production of synthesis gas (H₂, CO mixtures) from a number of sources. Most emphasis was devoted to coal and biomass (municipal solid waste and wood) gasification and new gasification technology. The report discussed downstream processing requirements and examined coal and biomass properties and their impact upon gasifier design. The economics of producing industrial fuel gas (gasifier effluent after acid gas removal) via different routes were compared to the direct use of natural gas and low sulfur fuel oil.

- HYDROGEN-SYNTHESIS GAS STUDY -- Nexant completed a Multiclient study on the production of hydrogen and synthesis gas from heavy oils and coal. The objective of this study was to analyze the effects on the U.S. natural gas shortage on that portion of the petrochemical industry dependent upon natural gas as a feedstock, with particular emphasis on ammonia, methanol, and hydrogen-based chemicals. The study included a section on comparative costs for all hydrocarbon feedstocks from natural gas to coal.
- COAL TO CHEMICALS - Visiting and Revisiting the Future -- This report provides a solid grasp of the state of development of coal to chemicals technologies, including an update on the status of such technologies as currently practiced in China, as well as providing a snapshot analysis of the most favorable coal to chemicals economics, on a mine-mouth basis, as compared to the production cost of the same product via petrochemical routes.

- WEST GERMAN COAL RESEARCH AND DEVELOPMENT/COAL GASIFICATION -- West German companies have undertaken a massive effort to update their technologies to meet motor fuels and chemical requirements from indigenous and imported coals. An unusually productive marriage of government and private money, deployed in pilot plants located in chemical and energy complexes, is steadily advancing the state of the art in West Germany. Promising United States technologies are also being considered and improved. This study reviewed and analyzed the individual programs for their merit and impact on synthetic fuels and coal-based chemicals projects in the industrialized countries.

- EVALUATION OF COAL BASED AMMONIA/METHANOL PROJECT -- Nexant developed the overall facilities concept and developed capital cost estimates for this project. Lurgi and Koppers-Totzek gasifiers were studied in detail. Internal steam and power balances were developed and the optimal synthesis gas processing sequence was developed.

- EVALUATION OF COAL/NATURAL GAS BASED METHANOL/POWER -- Nexant developed the overall facilities concept and capital cost estimates for an integrated complex employing "second generation" coal gasification, steam/methane reforming and combined cycle power generation technologies for the co-production of methanol and power. Relative coal and natural gas consumption was based on producing a stoichiometrically balanced methanol synthesis gas from coal-based hydrogen deficient and natural gas based carbon deficient synthesis gases.

- COAL TAR CHEMICALS -- In response to a Japanese company's request for an analysis of coal tar chemicals, Nexant conducted a study of U.S. and West European markets/applications and evaluated the technology for four basic coal tar chemicals and specific hydrogenated derivatives. The compounds studied included tetralin, biphenyl, acenaphthene, phenanthrene, and hydrogenated derivatives of acenaphthene and phenanthrene. The technology review covered all aspects of the chemistry of these materials as well as all applications and developments worldwide.

- IMPACT OF COAL CONVERSION PLANTS ON AROMATICS -- For a U.S. chemical company, Nexant assessed the economic feasibility of aromatics recovery from byproducts streams of coal gasification and coal liquefaction plants. Production technology and economics are provided for benzene, toluene, phenol, cresol, xylenol, and coal derived naphtha.

- SMOKELESS FUELS FROM COAL -- For a specialty fuel producer, Nexant identified and characterized methods for producing smokeless briquettes that met international standards and identified potential binders that could be used with existing equipment to produce smokeless briquettes that could be used for export. Binders studied included: coal tar pitch, petroleum resin, coal and starch.

- MARKETING ASSESSMENTS OF COAL PRODUCTS/BYPRODUCTS -- Nexant, under contract to Tri-State Synfuels Company (a partnership between Texas Eastern Synfuels Inc. and Texas Gas Synfuel Corporation) examined in detail the marketability of products from a Lurgi/Fischer-Tropsch coal-based facility being considered for Henderson, Kentucky. The coal conversion facility was being evaluated by Tri-State under a cooperative funding agreement with the U.S. Department of Energy. The products from the plant included high Btu substitute natural gas (SNG) liquid transportation and heating fuels, and a wide range of chemical products and byproducts. Nexant analyzed the general eight-state region surrounding the proposed plant. Recommendations and observations were made relating to possible changes in the originally envisioned slate of products.
that might improve the project's revenue generation capability. Future product prices and values were forecast, based on Nexant's prevailing long-term prognosis of energy, petroleum and petrochemical demands. Nexant performed two similar market analysis studies for New York Power Authority (NYPA). One involved a proposed 600 MW coal gasification combined cycle power plant considered for the Buffalo area. Nexant analyzed current and future markets for the fuels and chemicals (including synthesis gas derivatives) that could be manufactured in the complex. The second study was for a coal gasification plant being evaluated by NYPA for the South Bronx. Products considered for this plant included medium-Btu gas (and potential products) steam, sulfur, carbon dioxide and industrial gases (oxygen, nitrogen and argon)

- **VALUE OF COED PROCESS COAL-DERIVED LIQUIDS IN A PETROLEUM REFINERY** -- This study analyzed the value of liquids produced in a plant designed to make synthetic crude oil from coal

- **VALUE OF LIQUIDS PRODUCED FROM COAL IN A COG (COAL, OIL GAS) REFINERY** -- This study, for the Pittsburgh & Midway Coal Mining Company, determined the value of coal-derived liquids in petroleum refineries

- **COAL-METHANOL SLURRY PREFEASIBILITY STUDY** -- This study analyzed the economic viability of using coal-methanol slurry fuels in Malaysia

- **COAL-LIQUID MIXTURE** -- Assistance was provided to the U.S. Synthetic Fuels Corp., on oil, water and methanol coal mixture technologies, economics and markets in regard to defining the scope for a planned solicitation

- **COAL MINE ASSETS APPRAISAL** -- Certain coal mining equipment (mobile and fixed) and systems were evaluated and appraised in support of a lease financing

- **EVALUATION OF COAL TO SYNTHETIC GASOLINE PROJECT** -- This project compared the attractiveness of gasoline production from coal derived methanol via the Mobil MTG (methanol-to-gasoline) process, to the economics of direct coal liquefaction as well as coal based methyl fuel production

- **CHEMICALS FROM COAL AND SHALE** -- This study was performed under an RANN grant by the Office of Energy R&D Policy, NSF. The objectives of this study were: estimate feedstock demands for major organic chemicals; gauge the probable timing as to when chemical feedstock demands will constitute an unreasonably large fraction of conventional hydrocarbon sources; identify the potential technologies for (a) transformation of coal and shale building blocks to primary organic chemical building blocks or feedstocks, and (b) synthesis of current "petrochemicals" from such coal and shale-derived building blocks; define research and development strategies and a related program to assure that any conversion of the organic chemical industry to coal and shale would be based upon available and the most economically possible technology

- **SYNTHESIS GAS FOR CHEMICALS** -- This Multiclient report dealt with the applicability of emerging synthesis gas based routes to chemicals compared to traditional production methods. The synthesis gas based routes were analyzed based on the economics of large-scale production of synthesis gas from coal
Section 6  

Contact Information

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