

NexantThinking™

Special Reports

**On-Purpose Propylene in an Era of
Uncertainty**

Brochure
January 2016





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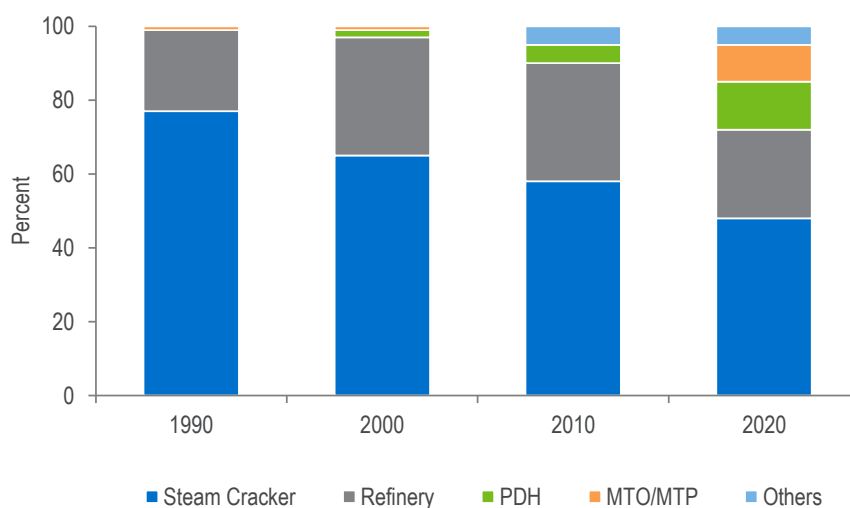
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1.1 SUMMARY OF THIS SPECIAL REPORT

Propylene demand is primarily satisfied with co-product propylene supplied from steam crackers for ethylene production, supplemented by off-gas co-product from the fluid catalytic cracking (FCC) process in oil refineries. Until 2000, these two conventional sources were nearly sufficient to meet global propylene demand. Since 2000, increasing on-purpose propylene supplies have been required to meet global propylene demand, which now totals over 90 million tons per year. With a 5 percent plus growth rate for propylene derivatives and a shift, in many regions, to cracking lighter feedstocks (ethane and LPG) instead of naphtha, the relative supply of propylene from steam crackers has declined, and the low growth of propylene supply from refineries has not been sufficient to keep pace with demand.

In the future, Nexant has long forecasted that these trends will accelerate, as the shale gas revolution leads to additional ethane-based steam crackers in North America and elsewhere. Consequently, as shown in Figure 1.1, Nexant forecasts that newly constructed on-purpose propylene (OPP) capacity based on propane dehydrogenation (PDH), methanol-to-olefins (MTO), or methanol-to-propylene (MTP) will account for 70 percent of new propylene capacity between 2013 and 2020.

Figure 1.1 Increasing Global Capacity for On-Purpose Propylene
(Global, 1990-2020)



The selection of which OPP process to employ depends on local feedstock availability, economics, and, in the case of China, feedstock security. In the United States, due to inexpensive propane from shale gas, there have been at least eight announcements of new PDH capacity, totaling over 4 million tons per year, as well as a recent announcement by BASF of a world-scale methane-to-propylene complex on the U.S. Gulf Coast. In China, on the other hand, new on-purpose propylene capacity is slated to include a mix of domestic coal-based MTO/MTP units, hybrid units based on imported methanol, as well as by PDH units using imported propane feedstock.

In the second half of 2014, as growing shale oil supplies from the U.S. displaced crude oil imports, OPEC (and in particular, Saudi Arabia) decided to discontinue its historic role of managing crude oil prices by constraining or expanding supply. As a result, crude oil prices experienced notable volatility and declined by over 50 percent, leading to a rapid fall in the prices for petrochemicals such as naphtha, other cracker feedstocks, ethylene, and cracker co-products. Over a period of six months, the competitive economics for ethane-based steam crackers in the United States moved much closer to parity versus alternative

feedstocks (especially propane and butane). Simultaneously, as a result of monetary conditions in the United States and sentiment in currency markets, there has been significant strengthening of the U.S. dollar. Although naphtha crackers remain disadvantaged, the combined impact of lower oil prices and the strengthening U.S. dollar has improved the relative competitiveness of European and Asian steam crackers and resin producers and likely delayed the consideration of if, or when, to shut down marginal (previously unprofitable, but now nearly competitive) capacity. Furthermore, the uncertainty and timing of an oil price recovery has created board-room confusion about the short-term and long-term viability of planned export-driven olefins and polyolefins capacity in the United States and likely delayed final investment decisions for additional capacity. With the turmoil in the price of crude oil, the price spread between propylene and propane in the United States has declined by over 30 percent since November 2014. Yet, the economics of PDH (as well as MTO/MTP) are still favorable. This result begs the question:

With the uncertainty surrounding future oil prices, which on-purpose propylene technology is best in a given region in the long-run?

In the future, rapid growth of LPG shipping capacity and massive terminal construction on the U.S. Gulf coast will enable significant growth of propane exports, eventually impacting the supply/demand balance for propane and the economic assumptions justifying PDH units. Consequently, during this period of exceptional price volatility, it is critical that a robust feasibility analysis for on-purpose propylene will consider all these factors and model project profitability under most likely, as well as extreme, future oil price scenarios.

The objective of this special report is to carefully examine, in a volatile crude oil environment, the current and future market dynamics, technology and economics for feedstocks, olefins, and propylene in particular. This report will help project developers, lenders and customers understand which route to on-purpose propylene is advantaged in various regions of the world and the issues that might impact decision making in an era of uncertainty.

1.2 MEGATRENDS IMPACTING GLOBAL OLEFINS SUPPLY AND ECONOMICS

There are a number of megatrends impacting the supply and regional mix of olefins production:

- **Co-product Propylene Supply is Inadequate:** Co-product supplies from steam crackers and FCC units is not keeping pace with propylene demand growth of over 5%
 - **Weak Gasoline Demand Growth:** On average, global gasoline production is growing slower than GDP⁽¹⁾ and propylene demand, reducing growth of refinery based propylene supply
 - **Lighter Cracker Feedstocks:** Although naphtha and liquid cracking economics continue to remain disadvantaged vs. lighter NGLs, the gap has narrowed, creating uncertainty and delaying investment decisions regarding future olefins capacity
- **On-purpose Propylene Capacity is Required:** Imbalanced propylene supply and competitive economics via alternative feedstocks have driven interest in MTO/MTP and PDH for propylene in several regions
 - **New PDH capacity is Planned and Under Construction:** New sources of propane are leading to PDH investments in North America, Middle East and China
 - **Growing Coal/Methanol to Olefins Capacity in China:** China's energy security agenda and the apparent viability of the syngas to olefins route are encouraging a surge in coal/methanol based olefins

¹ Gasoline demand growth is slowing as vehicle fuel economy improves, demographics shift, and alternatives such as ethanol, diesel engines and hybrids gain share

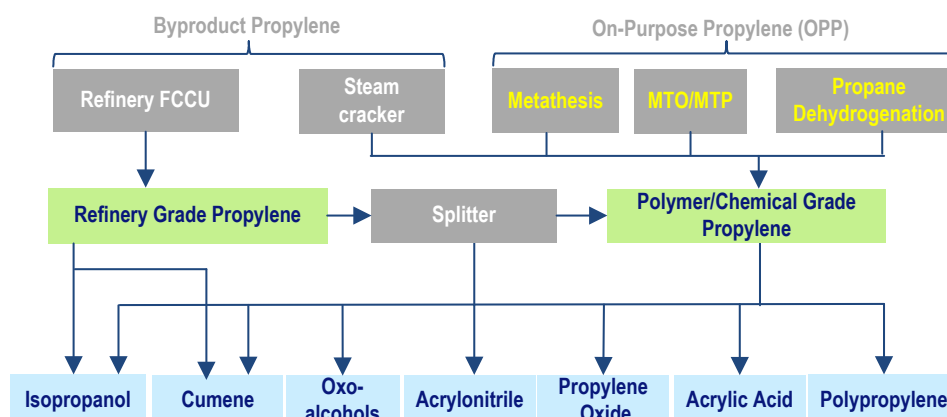
- **Oil price volatility and Market Based Crude Oil Pricing:** OPEC has abdicated its historic role of managing crude oil prices by manipulating supply and is instead focused on maintaining volume share.
 - **Naphtha has Become more Competitive for Crackers:** Lower oil prices have narrowed the competitive spread among various cracker feedstocks, *but not enough to impact the requirement for new on-purpose propylene*
- **Ample Shale Gas in the United States:** Although lower oil prices have temporarily reduced drilling intensity, natural gas and natural gas liquids (NGLs) supply continues to boom, creating new markets for exports of liquefied natural gas (LNG), ethane, ethylene, ethylene derivatives, and LPG
 - **New LPG Export Terminals:** Inexpensive propane and butane is leading to massive new LPG export capacity in the United States and will eventually lead to domestic propane prices based on export parity with other regions. At export parity, is there enough margin to cover the cost of capital for PDH units?
 - **Additional Ethane Terminals and Ships are Under Consideration:** Ethane is to be imported as cracker feedstock in Europe and India (and possibly other regions) from U.S. East Coast and USGC sources, leading to less propylene co-product production in regions where naphtha crackers were the primary source of supply
- **Economics for On-purpose Propylene Need Reconsideration:** With more volatile oil prices, the profitability and trade dynamics for olefins and polyolefins will be impacted
 - **Lower oil to gas ratio means lower profitability for PDH and MTO/MTP:** Given the huge investments required for world scale plants, developers need to understand how profitability and return on investment will be impacted under various oil price scenarios

Below, we provide some additional detail about some of these market-changing trends, which have contributed to considerable uncertainty about the long-term supply, price and regional economics of propylene.

1.2.1 Global Propylene Supply Dynamics

Propylene is largely produced as a co-product of other processes, namely steam crackers to make ethylene and from off-gas recovery from FCC units in refineries, as illustrated in Figure 1.2. Accordingly, the majority of propylene production is driven by demand for ethylene and gasoline. As a result, at times, the supply of propylene can get out of sync with the demand, leading to surpluses, deficits and price volatility.

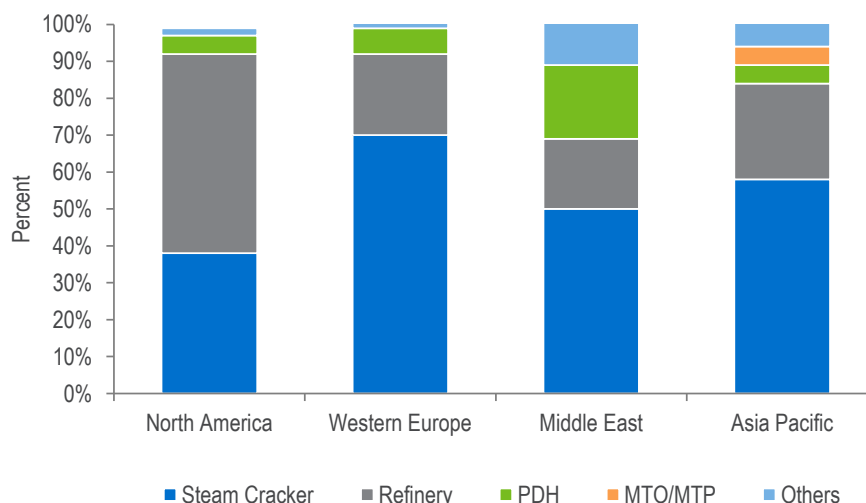
Figure 1.2 Propylene Value Chain



Propylene capacity mix varies by region depending on feedstock availability, olefin and gasoline demand dynamics and propylene process economics. For example, due to the predominant use of gasoline driven

cars in the United States, refinery sourced propylene capacity is relatively large in the United States compared to other regions, which rely on steam crackers for the majority of their base propylene capacity.

Figure 1.3 **Relative Regional Capacity for Propylene, 2013**
(Percent)



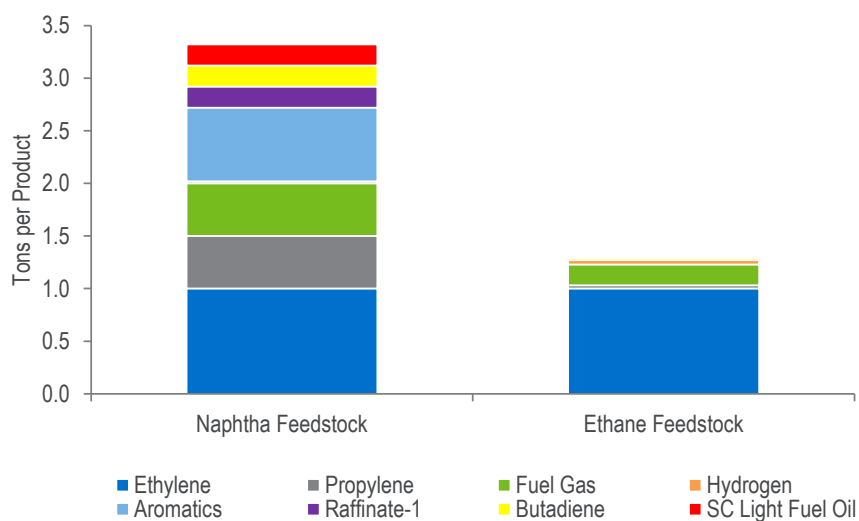
1.2.2 FCC Propylene Supply and Splitter Utilization

Although there is significant FCC capacity available in the United States, the quantity of propylene recovered and purified for chemical use depends on several factors. First of all, FCC feedstock, vacuum gas oil (VGO), is also a feedstock for hydrocrackers, which has led to higher VGO costs relative to crude oil. Secondly, advantaged feedstock for U.S. refineries (WTI crude oil is less expensive than Brent) have led to relatively high operating rates for U.S. refineries (and exports of gasoline). Thirdly, FCC propylene has an alternate use as feedstock for alkylate (alkylation value) and if octane values are high, this value can be higher than that of extracting/splitting the propylene for chemical uses. Finally, depending on seasonal refinery operations, chemical market value, logistics, shipping costs, and environmental regulations, refiners will continually evaluate whether or not to recover propylene. As refinery FCC capacity and splitter capacity is not expected to expand significantly in the United States, capacity of refinery sourced propylene will show little change. Growth in refinery grade propylene consumption is also limited by the low growth outlook for cumene and isopropanol into which most is consumed. While advantaged refinery-sourced propylene production in the United States has allowed producers to become major exporters of many propylene derivatives, the loss of propylene production from steam cracking has now reversed this effect. In the coming decade, the advent of advantaged OPP in the United States may reverse this effect yet again.

1.2.3 Olefins Supply Dynamics have Reduce Propylene Supply and Shifted the Propylene to Ethylene Price Ratio

As shown in Figure 1.4, the proportion of ethylene, propylene and butadiene (as well as aromatics and other products) produced by a steam cracker depends on the feedstock used and the operating conditions. All feedstocks for steam cracking produce ethylene. Heavier feedstocks (such as naphtha) produce a greater proportion of propylene and butadiene, the heavier olefins, per unit of ethylene output while steam crackers using light feedstocks such as ethane produce only minor amounts of propylene and butadiene.

Figure 1.4 Steam Cracker Products from Naphtha vs. Ethane
(Tons of Product per ton of Ethylene)



Ethylene Production

There are now three major poles of new ethylene capacity development: from coal/methanol feedstock in China, from low cost ethane in the United States and from NGLs and liquids in the Middle East. The continuing higher cost of naphtha relative to NGLs will greatly reduce the growth of naphtha based crackers, even in China. The shale gas revolution in the United States has radically improved the competitiveness of domestic ethylene production, and generated development projects for around ten million tons per year of additional ethylene capacity, through expansions and several new world-scale steam cracker complexes. Capacity development in the Middle East has slowed dramatically as a result of limited availability of additional ethane for new projects. As gas feedstocks become more difficult to obtain in the Middle East, there is a renewed focus on export oriented refinery and petrochemicals complexes. New steam cracker projects in the Middle East are based around the remaining allocations of ethane, or ethane combined with naphtha, which is currently exported in large quantities. In Europe and Asia, ethylene from naphtha crackers has become more competitive with the decline in oil prices. Nevertheless, producers in coastal areas are considering capital investment to allow alternative feedstocks such as LPG or even imported ethane, which will reduce the amount of propylene co-product.

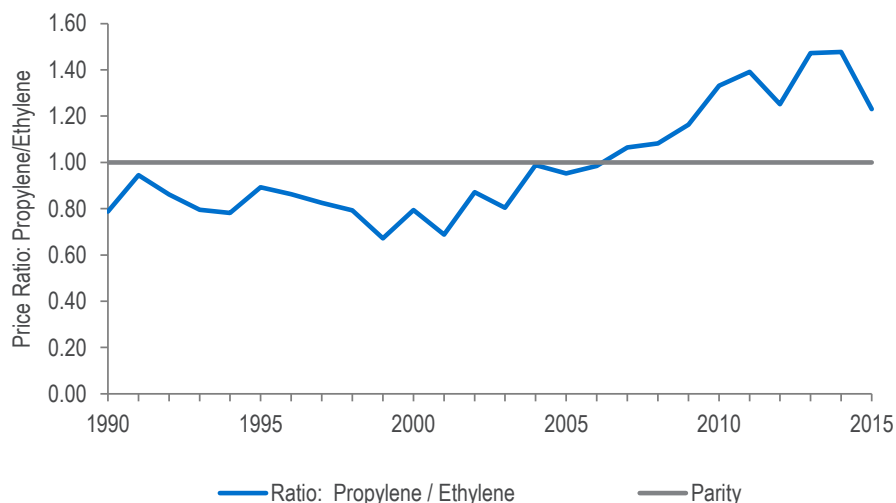
Propylene Production

In the United States, the volume of co-product propylene from steam cracking has dropped sharply as a result of the switch to lighter cracker feeds. Concurrently, propane supply has increased rapidly along with shale gas exploitation. As U.S. natural gas prices dropped, the prices of liquid petroleum gas (LPG) also declined, but remained closer to global levels, favoring exploitation of shale plays containing “wet gas”. This has been accompanied by major midstream gas separation investments, providing substantial growth in supply of propane and butanes. The shortage of propylene, and increase in propane availability will support the rapid expansion of propane dehydrogenation (PDH) capacity in the United States during the next five years. Furthermore, propane exports from the United States are set to increase, and PDH projects based on imported propane are being pursued in many regions (especially China) where there is strong demand for propylene and its derivatives.

Concurrent with the growth of lighter cracker feedstocks and less expensive ethylene, the growth of ethanol in gasoline has reduced U.S. demand for gasoline and flattened the supply of propylene from refinery sources. In total, lighter cracker feedstocks has removed almost 15 percent of the U.S. propylene supply since 2007. As a result, as shown in Figure 1.5, the price ratio of propylene to ethylene in the United States has reversed its long-term trend and propylene prices have moved from a 30 percent discount to ethylene

in 2000 to a premium of over 40 percent in 2013. In regions (Europe and Asia) that still crack naphtha to make ethylene, the price ratio of propylene to ethylene remains much closer to one.

Figure 1.5 Price Ratio: Propylene/Ethylene (USGC)



1.2.4 Methanol to Olefins (MTO) Technology in China

East Asia, driven by China, has been the main area of growth for olefins and olefin derivatives demand over the past few decades. Although a significant portion of this demand growth has been served by export-oriented capacity constructed in the Middle East, the majority has been fulfilled by new naphtha-fed steam cracker capacity in Asia proper (including China, Japan, Korea, and Singapore).

Recently, however, the Chinese chemicals industry has made a concerted push to diversify feedstocks away from crude oil-derived hydrocarbons, which must in large measure be imported, towards locally sourced coal. Supported by government policy, Chinese coal-to-chemicals projects have already developed into mature producers of chemicals from coal carbide-derived acetylene (PVC, vinyl acetate monomer, butanediol, acrylic acid) and from coal syngas (methanol, ammonia, urea, acetic acid). Further state policy initiatives have spearheaded the rapid commercialization of MTO (often with Olefin Cracking Process, or “OCP” unit) and MTP processes (from coal-based syngas) in China, displacing imported naphtha.

Methanol-based propylene production is actively developing in China, motivated by exploitation of large coal reserves. The world’s first commercial propylene unit using methanol feedstock began operation in China in 2010, followed by four new plants in 2011-2013. Collectively, the current nameplate capacity is over two million tons per year – and due to formidable Chinese experience in coal to chemicals technology has the potential to displace a large portion of future naphtha-fed steam cracker olefins capacity in China.

In addition, as discussed in more detail in Section 1.2.6, various Chinese companies have announced plans to produce methanol for export to China from advantaged natural gas in the United States. These “hybrid” units would provide methanol to coastal MTO/MTP units that compete with coal based MTO/MTP units in China’s interior.

1.2.5 Propylene Price Drivers

Since the majority of propylene is produced as a co-product, it is generally inappropriate to relate propylene prices to a cost of production. The major influences on propylene price movements can be attributed to fluctuations in the supply/demand balance and the cost/value of the incremental supply and alternative uses. The key drivers in determining propylene prices are:

- The cost of extracting propylene from refineries, allowing for the alternate value of refinery propylene to refinery end uses (including fuel, LPG, polygasoline and alkylate)
- The implied cost or advantage of moving to lower severity cracking. Typically lower severity cracking increases propylene and heavier co-product yields, but may be restricted by ethylene capacity
- The price that supports viable economic operation of marginal production processes (including propane dehydrogenation and metathesis). Currently, with high propylene values and low propane costs, PDH is very profitable (even with low oil prices) and does not provide a meaningful price floor
- Inter-regional propylene price relationship and the cost of freight between regions
- The profitability of propylene derivative products compared to producers in competing global markets
- The competitiveness of polypropylene compared to HDPE

Additional information on Nexant's margin and price forecasting analysis is provided in the methodology section of this prospectus.

1.2.6 Genesis of this Special Multi-client Report: Choices of Feedstock and Supply Chain

At present, propylene prices have remained high relative to ethylene in the U.S., and forecast production of on-purpose propylene is leading towards a significant shift in the regional supply mix for propylene and a marked shift in trade flows. However, the price of propylene in China has dropped well below ethylene. With announcements of seven new PDH units in North America based on advantaged propane, and with China to gain almost 10 million tons of coal-based MTO/MTP propylene capacity and over 6 million tons of PDH capacity based on imported propane, the 2020 global supply mix of propylene will look much different than today's mix.

In May 2014, BASF announced that it is evaluating a large investment in a world-scale methane-to-propylene complex on the U.S. Gulf Coast.⁽²⁾ Since the other North American OPP announcements had exclusively selected PDH technology, this is perhaps surprising, especially since methanol based olefins technology is significantly more capital intensive than PDH (per ton of propylene produced) and produces a more diverse (and complex) set of co-products.⁽³⁾ However, perhaps it is not such a surprise, since methane is highly advantaged on the Gulf Coast. And with the political (and increasing economic) barriers to building LNG terminals and the cost of shipping methane still formidable, it seems highly likely that U.S. based methane will maintain a long-term gap in price versus crude oil and naphtha.

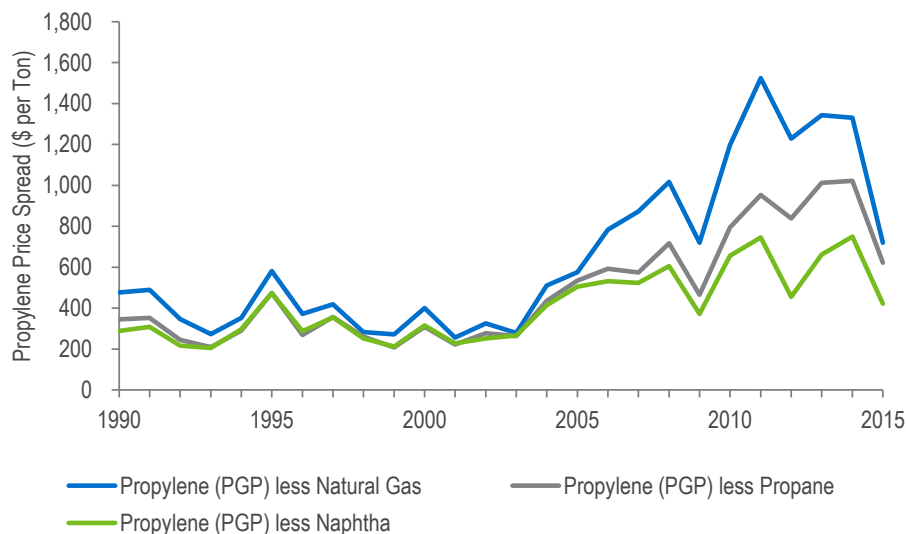
As shown in Figure 1.6, the price spread between propylene and natural gas has grown rapidly since 2003 and has exceeded the spread between propylene and propane by an average of \$353 per ton (USGC) since 2010. In addition, as propane (as LPG or propane) is much easier and less expensive to ship than methane (and a huge amount of LPG terminal capacity is scheduled to be built in the United States by 2016), a hypothesis that propane and naphtha prices will converge faster than methane and naphtha prices is not completely infeasible. *Depending on the speed and amount of convergence of propane and naphtha, PDH could possibly lose its competitive edge versus MTP.* Consequently, with a 30 year project life cycle,

² <http://www.basf.com/group/pressrelease/P-14-223>

³ Alpek/Indelpro is also considering both PDH and MTP according to public announcements.

it is reasonable to at least consider methane/methanol-based on-purpose propylene technology in North America - and perhaps other regions with supplies of low-priced stranded methane.

Figure 1.6 Propylene Price Spread for Alternative Feedstocks, USGC
(constant 2014 dollars per ton)



In addition to BASF's announcement, in the last year the intention to exclusively utilize the PDH process for new North American on-purpose propylene capacity has shifted slightly towards the Chinese mix of processes. As shown below, there have been several announcements of "hybrid" OPP capacity using U.S. shale gas to produce methanol for export to China to produce olefins.

- In April 2014, a joint venture between energy-giant BP and a collection of Chinese interests announced plans for at least two methanol plants to be built on the coast of Oregon and/or Washington, with the production slated for export to the Dalian Xishong Island Petrochemical Park in China, which would convert the methanol to olefins that would be used to make plastics and rubber
- In July 2014, Yuhuang Chemical and the State of Louisiana announced a capital investment of \$1.85 billion in a Louisiana methanol project, with 80 percent of production slated for export
- In July 2014, a third China-based group announced their interest in building huge methanol plant in the Houston area for export of up to 3.6 million tons per year of methanol to China⁽⁴⁾

These announcements of hybrid methanol-based OPP capacity provide a new way to ship American natural gas to China (albeit with a water molecule attached). However, in this era of uncertainty, this report will help the reader evaluate if this alternative value chain will be competitive with naphtha based steam crackers, coal-based methanol to propylene, or PDH units in China.

⁴ <http://cen.acs.org/articles/92/i30/PETROCHEMICALS-Chinese-firms-eye-construction.html>

1.3 REPORT OBJECTIVES AND KEY QUESTIONS:

These new announcements led Nexant to pose several important questions about on-purpose propylene and its alternative feedstocks, including:

Overall Strategic Questions:

- Where should Nexant's clients place their next increment of OPP capacity?
- Which OPP technology and feedstocks should they use?
- How does the ranking shift with oil at \$50/bbl, at \$85/bbl, or \$120 per barrel?
- Are there potential technical issues with existing OPP processes?

Feedstock Issues and Price Forecasts:

- What is the regional outlook for propylene feedstock prices (naphtha, coal, propane, methane)? What are the drivers of regional prices for these materials?
- With the massive amounts of new LNG and LPG export terminal capacity, what will happen to the domestic natural gas and LPG supply/demand balance and more importantly natural gas and propane prices both in the United States and in China?
- Will increasing LNG shipments lead to increased local prices for natural gas in the United States, Canada, Middle East, etc.? What about propane shipments and propane prices?
- What is the impact of low oil prices on feedstocks and co-product prices? How does the decreased spread between oil prices and natural gas impact the selection of OPP technology?
- Do hybrid schemes make sense? Which feedstocks, intermediates or propylene derivatives should be shipped to demand centers? Coal from Western China to Coastal China? Propane to China for PDH? Methanol to China for MTP? Or Propylene derivatives from USGC or Western Canada to Coastal China?

Propylene Supply:

- What is the sensitivity of OPP economics to coal, methane and propane prices? What will the propylene cost curve will look like regionally and globally after these new on-purpose propylene plants are completed?
- Which value chains will remain advantaged?
- What are the general technical and economic issues that impact the choice of on-purpose propylene technology?
- Given a supply of propane and regional demand for cracker co-products, is PDH more cost effective than steam cracking or metathesis?
- What are the co-products of MTP and PDH and how will companies manage these products?
- Can MTP plants in coastal China using delivered methanol compete against fully integrated methane to propylene derivatives, shipped to coastal China?
- What is the future price setting mechanism for propylene?
- What factors will influence the operating rates of new OPP capacity?
- Which OPP technology is best in a given region? Can hybrid OPP capacity, using U.S. shale gas to produce methanol for export to China to produce olefins, be successful?

The objective of Nexant's new multi-client study is to profile and assess current and future propylene market dynamics and economics. This multi-client report build's on Nexant's extensive array of intellectual capital in the areas of natural gas; methanol; coal-based chemicals; NGLs; propylene economics, supply and pricing; technology evaluation and analysis; and petrochemical market dynamics and regional competitiveness; to address the aforementioned key issues.

1.4 REPORT SUMMARY

This prospectus describes Nexant's multi-client study ***On-Purpose Propylene in an Era of Uncertainty***. The Prospectus includes an introduction to the topic, the objectives of the report, the scope of the proposed report, the methodology to be used, and Nexant's qualifications to perform such a study.

The study will:

- Address the global impact on propylene of the ongoing feedstock, refinery and demand trends in North America, Middle East and China
- Utilize Nexant's Global Petrochemical Industry Simulator and World Gas Model to forecast feedstock costs and the cost of propylene production in these regions via steam cracking and key relevant On-purpose Propylene technologies
- Repeat the above analysis under three different oil price scenarios (\$50, \$85, and \$120 per barrel)
- Provide critical sensitivity analyses for feedstocks prices, project scale, and estimated co-product values
- Detail the key issues that a project developer in each region should consider before undertaking an on-purpose propylene project

This study uses Nexant's cost of production models, proprietary industry simulators, and best critical thinking to predict which technology will be the low-cost OPP process in 2020 and 2030 by region as well as on a delivered cost basis (for polypropylene) to coastal China. The careful examination, and sensitivity analysis, of the impact of three oil price scenarios will provide the reader with a more nuanced understanding of how the economics of OPP could evolve in the future.

The report will provide a valuable resource for strategists, operators, investors, lenders and customers in deciding how to respond to a major shift in propylene availability and supply.

Nexant's new multi-client study, "On-Purpose Propylene in an Era of Uncertainty", was completed during Q4 2015.

2.1 REPORT OVERVIEW

The overall objective of this special report is to carefully examine the current and future market dynamics, technology and economics for feedstocks, olefins, and propylene in particular, in order to understand which route to on-purpose propylene is advantaged in various regions of the world; the issues that might impact decision making for various producers; and the impact of on-purpose propylene production on market dynamics and trade flows of propylene and derivatives. Specifically, we compare the 2015, 2020, 2025, and 2030 forecast cost of production for propylene and polypropylene for the project locations most likely to add significant capacity. In addition, we repeat the above analysis under three different oil price scenarios (\$50, \$85, \$120 per barrel). Nexant will provide results on a delivered to Shanghai, China basis (with duties) and include hybrid schemes (such as methanol made in the United States and delivered to China for MTP production of propylene) for the three petrochemical value chains illustrated below:

Figure 2.1 Ethane and Propane to Propylene (via Steam Cracking) to Polypropylene
(China, Kingdom of Saudi Arabia, 3 regions in North America)

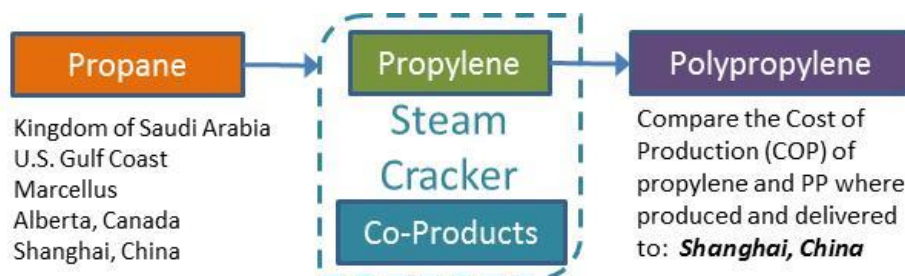


Figure 2.2 Propane to Propylene (via Propane Dehydrogenation) to Polypropylene
(China, Kingdom of Saudi Arabia, 3 regions in North America)

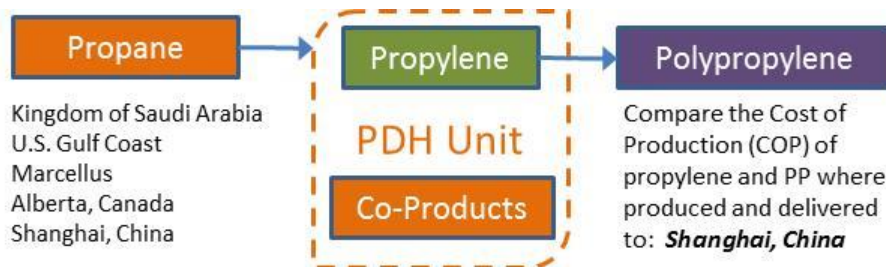
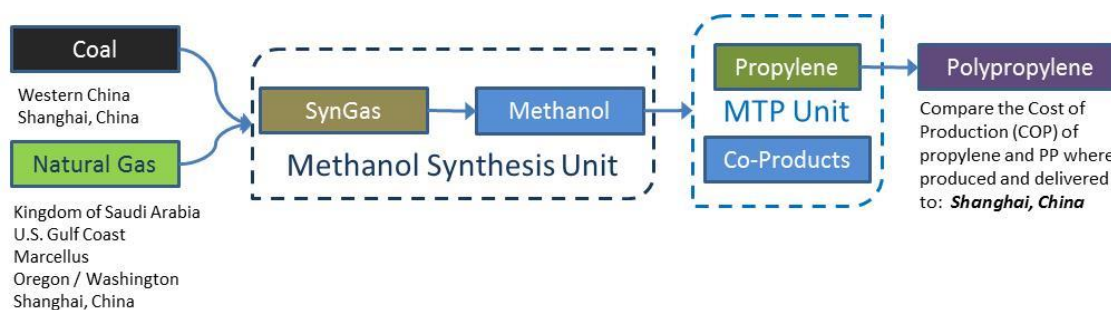


Figure 2.3 Syngas to Methanol to Propylene (via MTP and MTO) to Polypropylene
(2 regions in China (coal and natural gas), Kingdom of Saudi Arabia, 3 regions in United States)



The report will also review and forecast the resource and supply availability of coal, natural gas, ethane and propane, the pricing of these raw materials under three different oil price scenarios, and the resulting economics for producing propylene (and co-products) and polypropylene using a variety of feedstocks and process as described in detail below. Long term scenarios through to 2030 will be considered, assessing the key risks and uncertainties.

2.2 REPORT STRUCTURE

2.2.1 Trends Affecting the Propylene Supply/Demand Balance and Commercial Technologies

By-product Propylene Supply

Review current and forecast capacity and technologies for producing by-product propylene including options around refinery and steam cracking sources. This will include an analysis of FCCU propylene production and disposition, the shift to lighter cracker feedstocks, and the combined impact on propylene supply globally.

On-purpose Propylene Supply

Review in detail the current and forecast capacity and technologies for producing on-purpose propylene including propane dehydrogenation, metathesis, and methanol-based processes from coal and natural gas by region.

Global Propylene Demand by Derivative

Review current and forecast global demand for propylene for polypropylene, propylene oxide, acrylonitrile, cumene, acrylic acid, isopropanol and other derivatives.

Global Propylene Supply/Demand Balance by Region

Compare the current and forecast demand for propylene by region and the forecast trade flows for propylene and derivatives.

2.2.2 Existing Feedstock Markets and Price Forecasts

As explained in more detail in the methodology section of this prospectus, over the course of many years, Nexant has developed and optimized a proprietary simulation model of the global petrochemical industry, the Petrochemical Simulator. The simulation model is used to forecast petrochemical consumption, production and trade for all global countries or trading blocks forward to 2030. The integrated simulation model includes both the market dynamics of product flows and the economics of production costs, logistics, prices and profitability.

Crude Oil

For most chemicals, crude oil is the underlying cost driver. In the second half of 2014, as growing supplies of shale oil from the U.S. displaced crude oil imports, OPEC (and in particular, Saudi Arabia) decided to abdicate its historic role of managing crude oil prices. As a result, crude oil experienced notable volatility and declined by over 50%, leading to a rapid fall in the prices for naphtha, other cracker feedstocks, ethylene, and cracker co-products. Over a period of six months, the competitive economics for ethane-based steam crackers in the United States moved much closer to parity versus alternative feedstocks (especially propane and butane). The high volatility in crude oil markets due to global geo-political factors (OPEC, conflicts, weather, technology, etc.) and changes in technology (increasing shale oil supply and extraction efficiency) compounds the difficulty of accurately forecasting crude-oil prices. Consequently, Nexant Petrochemical Simulator is based on three crude oil scenarios (low, medium and high) as shown in Section 4.4.1. The report will explain the basis for the three crude oil price scenarios.

Naphtha

Naphtha is traded globally, and with the advent of shale oil and gas, both the supply side (additional LVN in North America from shale oil) and the demand side (global economic preference to crack lower cost NGLs instead of naphtha where possible) have shifted. In addition, light naphtha prices have become discounted to heavy naphtha used as feedstock for reformers and the increasing use of excess low cost LVN as gasoline feedstock has driven up octane values.

The report will offer and explain current and forecast naphtha market dynamics and price forecasts for the regions of interest and how naphtha prices are impacted under various crude oil scenarios.

Natural Gas

As explained in more detail in the methodology section of this prospectus, over the course of many years, Nexant has developed and optimized a proprietary model of the natural gas market, the World Gas Model (WGM). The WGM is Nexant's in-house database of global gas markets and includes supply, demand, international trade, infrastructure utilization, and price projections under different scenarios. 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 report will provide the WGM current and prospective natural gas prices at the wholesale level and for gas as a feedstock in Saudi Arabia, China, U.S. Gulf Coast, and U.S. West Coast and how natural gas prices are impacted under the three crude oil scenarios.

Ethane

In North America, new ethane export terminals are under consideration on the East Coast and Gulf Coast to supply steam crackers in Europe and Asia. Although there has not been an announcement of exports of ethane to China, it is certainly under consideration in boardrooms across the region. The impact of these exports on future ethane prices will depend on whether there will be enough overall demand from new domestic crackers and exports to soak up the current excess of ethane being rejected into natural gas supplies. Nexant will analyze this critical and evolving supply demand balance to forecast the future impact on ethane prices. In addition, we will perform sensitivity analysis with alternative price scenarios.

The report will provide Nexant's forecast for ethane prices in Saudi Arabia, China, U.S. Gulf Coast, and Alberta, Canada and how ethane prices are impacted under three crude oil scenarios.

Propane

In North America, LPG export terminals are under construction, and North America is expected to join the Middle East and Africa as key sources of LPG supply to Asia/Pacific. Exports to Europe are also expected to increase with the lower freight rate resulting in some competition for spot exports between Europe and Asia. These exports of propane are expected to be the swing consumer of propane from gas plants, and as the marginal source of demand, directly affect the price setting mechanism for propane in the United States. With the price of propane dependent on export parity economics to China, which will source LPG from a variety of sources, the equilibrium price of propane will impact the economics of the planned PDH capacity in both China and the United States. Nexant will analyze this critical supply demand balance to forecast the future price impact on propane. In addition, we will perform sensitivity analysis with alternative price scenarios.

The report will provide Nexant's forecast for propane prices in Saudi Arabia, China, U.S. Gulf Coast, and Alberta, Canada and how propane prices are impacted under various crude oil scenarios.

Coal

The report will provide Nexant's forecast for thermal coal prices at mine mouth in Western China and delivered to Shanghai, China.

2.2.3 Comparative Economics for Propylene and Polypropylene

With the shale gas advantage and the forthcoming investment in PDH capacity in North America, it is possible to imagine the United States will join Saudi Arabia in supplying exports of propane, propylene and polypropylene. Furthermore, as hybrid schemes involving methanol or propylene export are also under consideration, and since China is expected to be an importer of all of these commodities, as well as LNG, we find it reasonable to use as a basis for comparison, the delivered cost of propylene and polypropylene to Shanghai, China from domestic and primary imported sources. Nexant will also make the comparison between domestic production in Shanghai, China (from imported feedstocks) and production of propylene and polypropylene in Western China (from coal), delivered to Shanghai.

Propylene capacity will be a nominal 500 kta for each technology evaluated up to the world class scale limit. Capital costs are estimated for the "instantaneous" investment in the first quarter of 2015 and the estimated cost of production will be provided for 2015, 2020, 2025 and 2030 under three different oil price scenarios. Most historic prices and operating costs are from Nexant's internal databases and established third party pricing sources, while a few values have been obtained from industry contacts. Forecasts of feedstock and co-product prices are based on Nexant's Global Petrochemical Industry Simulator as outlined in Section 4 of this prospectus.

Table 2.1 shows the feedstocks and processes to produce propylene that will be compared.

Table 2.1 Feedstock and Processes for Comparison

Four Feedstocks	How: Seven Processes	Where:	
		Eight Regions	Many Hybrids
Local or Imported Ethane	Steam Cracking, Ethylene Dimerization, Metathesis	KSA, USGC, Marcellus, Alberta, Shanghai	Ship ethane, propane or propylene to Shanghai to make PP
Local or Imported Propane	Propane Dehydrogenation (PDH)		
	Steam Cracking, with propylene and C4 recovery		
Coal from Western China	Polygeneration to Syngas, Methanol Synthesis, Methanol to Propylene (MTP)	Western China, Shanghai	Ship coal, methanol, or propylene to Shanghai to make PP
	Polygeneration to Syngas, Methanol Synthesis, Methanol to Olefins (MTO) with OCP		
Local or Imported Natural Gas	Reforming to Syngas, Methanol Synthesis, Methanol to Propylene (MTP)	KSA, USGC, Marcellus, Oregon, Shanghai	Ship natural gas, methanol or propylene to Shanghai to make PP
	Reforming to Syngas, Methanol Synthesis, Methanol to Olefins (MTO) with OCP		

What is the most economical material to ship to China?

- **Feedstock**
 - Ethane
 - Propane
 - Coal
 - Gas
- **Intermediate**
 - Methanol
- **Propylene**
- **Polypropylene**

How do economics shift with Brent oil price scenarios?

- **\$50 / barrel**
- **\$85 / barrel**
- **\$120 / barrel**

For steam cracking routes, Nexant will compare the economics of a basic stream cracker with propylene and C4 recovery, to a unit that also includes dimerization and metathesis unit to maximize propylene production.

For methanol based routes, Nexant will compare the cost of production of a MTP unit to an MTO unit with the Olefin Cracking Process (OCP) from UOP.

The following list and tables illustrate the 66 cases that will be developed by technology and region for each of three crude oil price scenarios:

- Steam Cracking of Ethane with Metathesis (SCEM): 8 regional cases with hybrids
- Steam Cracking of Propane with Metathesis (SCPM): 8 regional cases with hybrids
- Steam Cracking of Propane (SCP): 8 regional cases with hybrids
- Propane Dehydrogenation (PDH): 8 regional cases with hybrids
- Coal to Propylene (CTP) via MTP: 4 regional cases with hybrids
- Coal to Olefins (CTO) with OCP: 4 regional cases with hybrids
- Natural Gas to Propylene (GTP) via MTP: 13 regional cases with hybrids
- Natural Gas to Olefins (GTO) via MTO with OCP: 13 regional cases with hybrids

Table 2.2 Ethane to Polypropylene via Steam Cracking with Metathesis
(8 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus	Hybrid: Alberta Propylene to Shanghai, China	Alberta, Canada
Process Steps	Cost to make propylene via Steam Cracking from:	Imported Ethane		KSA Ethane		USGC Ethane		Marcellus Ethane		Alberta Ethane
	Cost to make Polypropylene from:	Shanghai Propylene	KSA Propylene	KSA Propylene	USGC Propylene	USGC Propylene	Marcellus Propylene	Marcellus Propylene	Alberta Propylene	Alberta Propylene
Logistics & Duties	Import Ethane to Shanghai	Via Ship								
	Import Propylene to Shanghai		Via Ship		Via Ship		Via Ship		Via Ship	
	Import Polypropylene to Shanghai			Via Ship		Via Ship		Via Ship		Via Ship
	Duties	Ethane	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case SCEM 1	Case SCEM 2	Case SCEM 3	Case SCEM 4	Case SCEM 5	Case SCEM 6	Case SCEM 7	Infeasible	Case SCEM 8

Table 2.3 Propane to Polypropylene via Steam Cracking with Metathesis
(8 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus	Hybrid: Alberta Propylene to Shanghai, China	Alberta, Canada
Process Steps	Cost to make propylene via Steam Cracking from:	Imported Propane		KSA propane		USGC propane		Marcellus propane		Alberta propane
	Cost to make Polypropylene from:	Shanghai Propylene	KSA Propylene	KSA Propylene	USGC Propylene	USGC Propylene	Marcellus Propylene	Marcellus Propylene	Alberta Propylene	Alberta Propylene
Logistics & Duties	Import Propane to Shanghai	Via Ship			Via Ship		Via Ship		Via Ship	
	Import Propylene to Shanghai		Via Ship		Via Ship		Via Ship		Via Ship	
	Import Polypropylene to Shanghai			Via Ship		Via Ship		Via Ship		Via Ship
	Duties	Propane	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case SCPM 1	Case SCPM 2	Case SCPM 3	Case SCPM 4	Case SCPM 5	Case SCPM 6	Case SCPM 7	Infeasible	Case SCPM 8

Table 2.4 Propane to Polypropylene via Steam Cracking
(8 cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus	Hybrid: Alberta Propylene to Shanghai, China	Alberta, Canada
Process Steps	Cost to make propylene via Steam Cracking from:	Imported Propane		KSA propane		USGC propane		Marcellus propane		Alberta propane
	Cost to make Polypropylene from:	Shanghai Propylene	KSA Propylene	KSA Propylene	USGC Propylene	USGC Propylene	Marcellus Propylene	Marcellus Propylene	Alberta Propylene	Alberta Propylene
Logistics & Duties	Import Propane to Shanghai	Via Ship								
	Import Propylene to Shanghai		Via Ship		Via Ship		Via Ship		Via Ship	
	Import Polypropylene to Shanghai			Via Ship		Via Ship		Via Ship		Via Ship
	Duties	Propane	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case SCP 1	Case SCP 2	Case SCP 3	Case SCP 4	Case SCP 5	Case SCP 6	Case SCP 7	Infeasible	Case SCP 8

Table 2.5 Propane to Polypropylene via Propane Dehydrogenation
(8 Cases, Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus	Hybrid: Alberta Propylene to Shanghai, China	Alberta, Canada
Process Steps	Cost to make propylene via PDH from:	Imported Propane		KSA propane		USGC propane		Marcellus propane		Alberta propane
	Cost to make Polypropylene from:	Shanghai Propylene	KSA Propylene	KSA Propylene	USGC Propylene	USGC Propylene	Marcellus Propylene	Marcellus Propylene	Alberta Propylene	Alberta Propylene
Logistics & Duties	Import Propane to Shanghai	Via Ship								
	Import Propylene to Shanghai		Via Ship		Via Ship		Via Ship		Via Ship	
	Import Polypropylene to Shanghai			Via Ship		Via Ship		Via Ship		Via Ship
	Duties	Propane	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case PDH 1	Case PDH 2	Case PDH 3	Case PDH 4	Case PDH 5	Case PDH 6	Case PDH 7	Infeasible	Case PDH 8

Table 2.6 Coal to Polypropylene via MTP
(4 Cases, Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: Western China MeOH to Shanghai, China	Hybrid: Western China Propylene to Shanghai, China	Western China
Process Steps	Compare Cost to make Syngas from:	Coal from Western China			Local Thermal Coal
	Compare cost of MeOH from:	Shanghai Syngas			Western China Syngas
	Cost to make propylene via MTP from:	Shanghai MeOH	Western China MeOH		Western China MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	Western China Propylene	Western China Propylene
Logistics	Transport Coal to Shanghai	Via Train			
	Transport Methanol to Shanghai		Via Train		
	Transport Propylene to Shanghai			Via Train	
	Transport Polypropylene to Shanghai				Via Train
Total Cost of Polypropylene in Shanghai		Case CTP1	Case CTP2	Case CTP3	Case CTP4

Table 2.7 Coal to Polypropylene via MTO with OCP
(4 Cases, Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: Western China MeOH to Shanghai, China	Hybrid: Western China Propylene to Shanghai, China	Western China
Process Steps	Compare Cost to make Syngas from:	Coal from Western China			Local Thermal Coal
	Compare cost of MeOH from:	Shanghai Syngas			Western China Syngas
	Cost to make propylene via MTO with OCP from:	Shanghai MeOH	Western China MeOH		Western China MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	Western China Propylene	Western China Propylene
Logistics	Transport Coal to Shanghai	Via Train			
	Transport Methanol to Shanghai		Via Train		
	Transport Propylene to Shanghai			Via Train	
	Transport Polypropylene to Shanghai				Via Train
Total Cost of Polypropylene in Shanghai		Case CTO1	Case CTO2	Case CTO3	Case CTO4

Table 2.8 Natural Gas to Polypropylene via MTP
(13 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA MeOH to Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			KSA Syngas
	Cost to make propylene via MTP from:	Shanghai MeOH	KSA MeOH		KSA MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	KSA Propylene	KSA Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTP 1	Case GTP 2	Case GTP 3	Case GTP 4

	Cost Element \ Production Location	Shanghai, China	Hybrid: USGC MeOH to Shanghai, China	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			USGC Syngas
	Cost to make propylene via MTP from:	Shanghai MeOH	USGC MeOH		USGC MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	USGC Propylene	USGC Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTP 1	Case GTP 5	Case GTP 6	Case GTP 7

Table 2.8 Natural Gas to Polypropylene via MTP (Continued)
(13 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: Marcellus MeOH to Shanghai, China	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			Marcellus Syngas
	Cost to make propylene via MTP from:	Shanghai MeOH	Marcellus MeOH		Marcellus MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	Marcellus Propylene	Marcellus Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTP 1	Case GTP 8	Case GTP 9	Case GTP 10

	Cost Element \ Production Location	Shanghai, China	Hybrid: West Coast MeOH to Shanghai, China	Hybrid: West Coast Propylene to Shanghai, China	Oregon / Washington (West Coast)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			West Coast Syngas
	Cost to make propylene via MTP from:	Shanghai MeOH	West Coast MeOH		West Coast MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	West Coast Propylene	West Coast Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTP 1	Case GTP 11	Case GTP 12	Case GTP 13

Table 2.9 Natural Gas to Polypropylene via MTO with OCP
(13 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: KSA MeOH to Shanghai, China	Hybrid: KSA Propylene to Shanghai, China	Kingdom of Saudi Arabia (KSA)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			KSA Syngas
	Cost to make propylene via MTO with OCP from:	Shanghai MeOH	KSA MeOH		KSA MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	KSA Propylene	KSA Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTO 1	Case GTO 2	Case GTO 3	Case GTO 4

	Cost Element \ Production Location	Shanghai, China	Hybrid: USGC MeOH to Shanghai, China	Hybrid: USGC Propylene to Shanghai, China	U.S. Gulf Coast (USGC)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			USGC Syngas
	Cost to make propylene via MTO with OCP from:	Shanghai MeOH	USGC MeOH		USGC MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	USGC Propylene	USGC Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTO 1	Case GTO 5	Case GTO 6	Case GTO 7

	Cost Element \ Production Location	Shanghai, China	Hybrid: Marcellus MeOH to Shanghai, China	Hybrid: Marcellus Propylene to Shanghai, China	Marcellus
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			Marcellus Syngas
	Cost to make propylene via MTO with OCP from:	Shanghai MeOH	Marcellus MeOH		Marcellus MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	Marcellus Propylene	Marcellus Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTO 1	Case GTO 8	Case GTO 9	Case GTO 10

Table 2.9 Natural Gas to Polypropylene via MTO with OCP (Cont'd.)
(13 Cases Including Hybrids)

	Cost Element \ Production Location	Shanghai, China	Hybrid: West Coast MeOH to Shanghai, China	Hybrid: West Coast Propylene to Shanghai, China	Oregon / Washington (West Coast)
Process Steps	Compare Cost to make Syngas from:	Imported LNG			Local Natural Gas
	Compare cost of MeOH from:	Shanghai Syngas			West Coast Syngas
	Cost to make propylene via MTO with OCP from:	Shanghai MeOH	West Coast MeOH		West Coast MeOH
	Cost to make Polypropylene from:	Shanghai Propylene	Shanghai Propylene	West Coast Propylene	West Coast Propylene
Logistics & Duties	Import Natural Gas to Shanghai	Via Ship			
	Import Methanol to Shanghai		Via Ship		
	Import Propylene to Shanghai			Via Ship	
	Import Polypropylene to Shanghai				Via Ship
	Duties	LNG	Methanol	Propylene	Poly-propylene
Total Cost of Polypropylene in Shanghai		Case GTO 1	Case GTO 11	Case GTO 12	Case GTO 13

2.2.4 Regional Market Analysis

For each region (North America, Western Europe, Middle East, and Asia Pacific) the report will provide recent and projected propylene capacity, demand for propylene derivatives, net trade dynamics and estimated pricing for propylene as follows:

Co-Product Propylene

Review current and forecast capacity to produce co-product propylene by technology.

On-Purpose Propylene

Review in detail the current and forecast capacity to produce on-purpose propylene by technology including via propane dehydrogenation, metathesis, and methanol-based processes from coal, natural gas or other feedstocks.

Global Propylene Demand by Derivative

The report will review current and forecast demand for propylene for polypropylene, propylene oxide, acrylonitrile, cumene, acrylic acid, isopropanol, and others.

Global Propylene Supply/Demand Balance by Region

Compare the current and forecast demand for propylene by region and the forecast trade flows for propylene and derivatives.

2.2.5 Key Issues and Study Conclusions

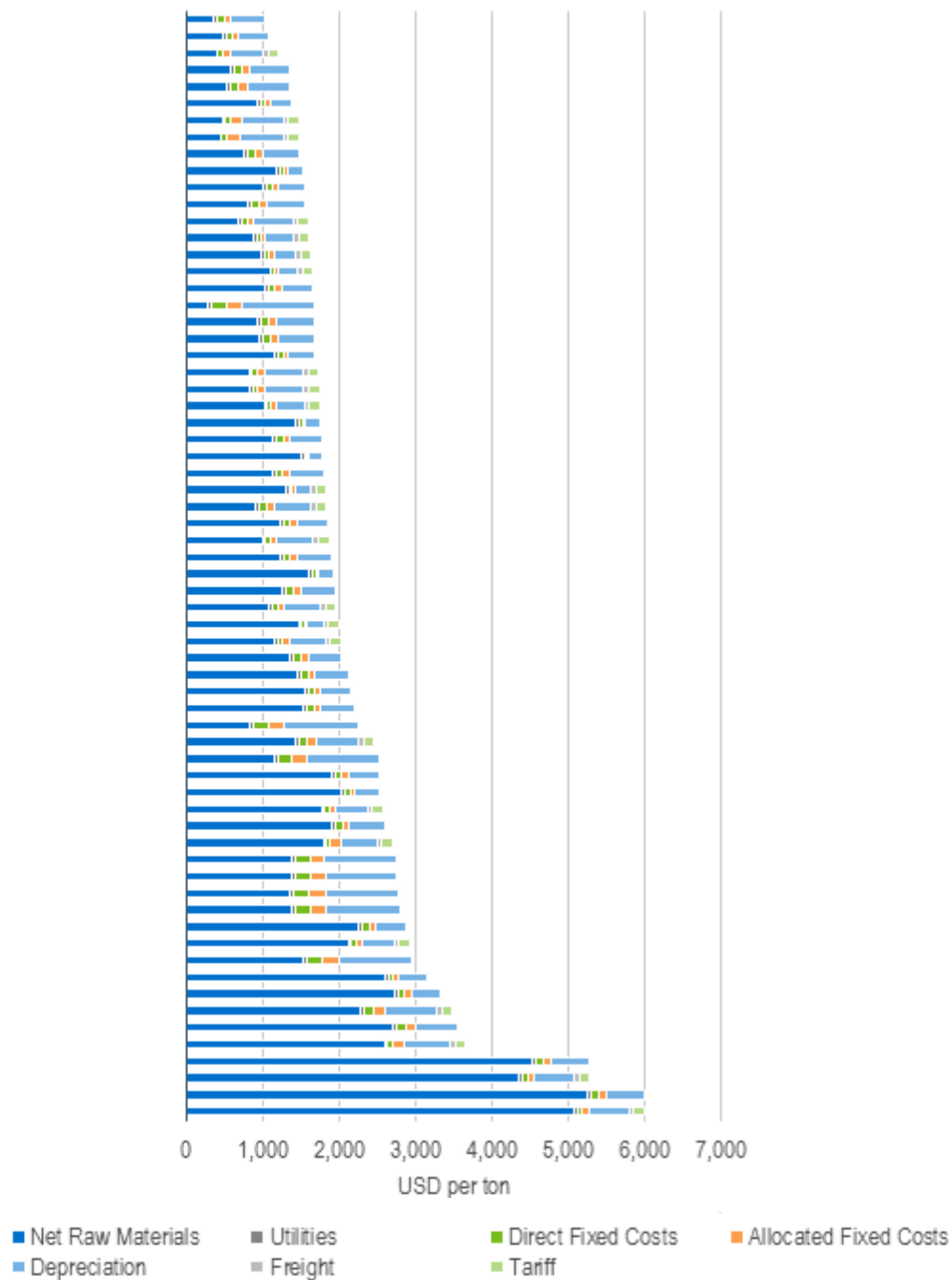
What Is the Winning On-Purpose Propylene Technology for Each Region?

Nexant will compare and rank the best feedstocks, processes and hybrid processes for propylene and polypropylene for each region. This will include a comparison within regions to understand the low cost process by region as well a comparison across regions to understand the lowest delivered cost to Shanghai, China.

As an example of the analysis included in the report, the figure below compares the cost of production for polypropylene for the various process/region options as delivered to Shanghai in 2025 using the high oil

price scenario. There is a wide range of variable and fixed costs, which impacts the competitiveness of the various processes and regions. Many of the options are highly competitive, while other are not.

Figure 2.4 Competitiveness as delivered to Shanghai in 2025, Polypropylene
(High Oil Price Scenario)

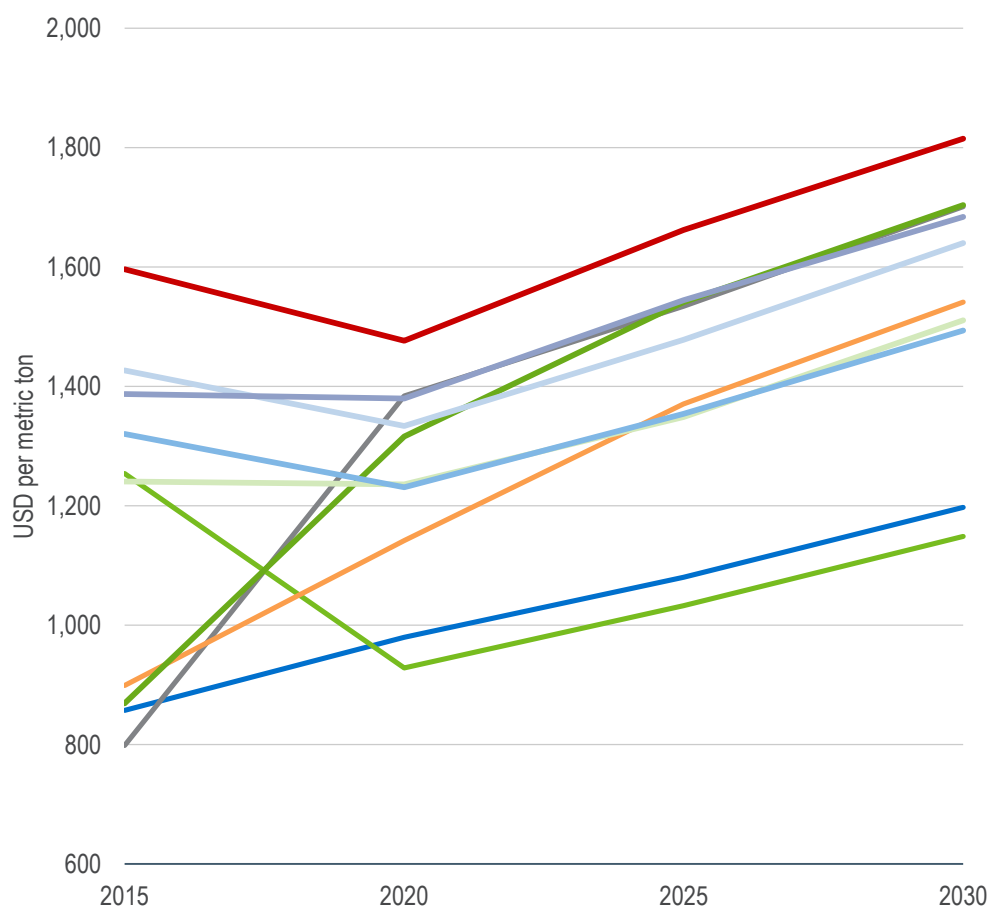


Sensitivity Analysis

The primary analysis will be based on Nexant's \$85/bbl crude oil scenario. However; Nexant will also provide a sensitivity analysis to examine the economics of alternative feedstock prices using Nexant's \$50/bbl and \$120/bbl (constant \$2015) price scenarios. As the prices of the key raw materials vary in their sensitivity to oil prices, the results of this analysis show which processes are most competitive in each region depending on the oil price outlook.

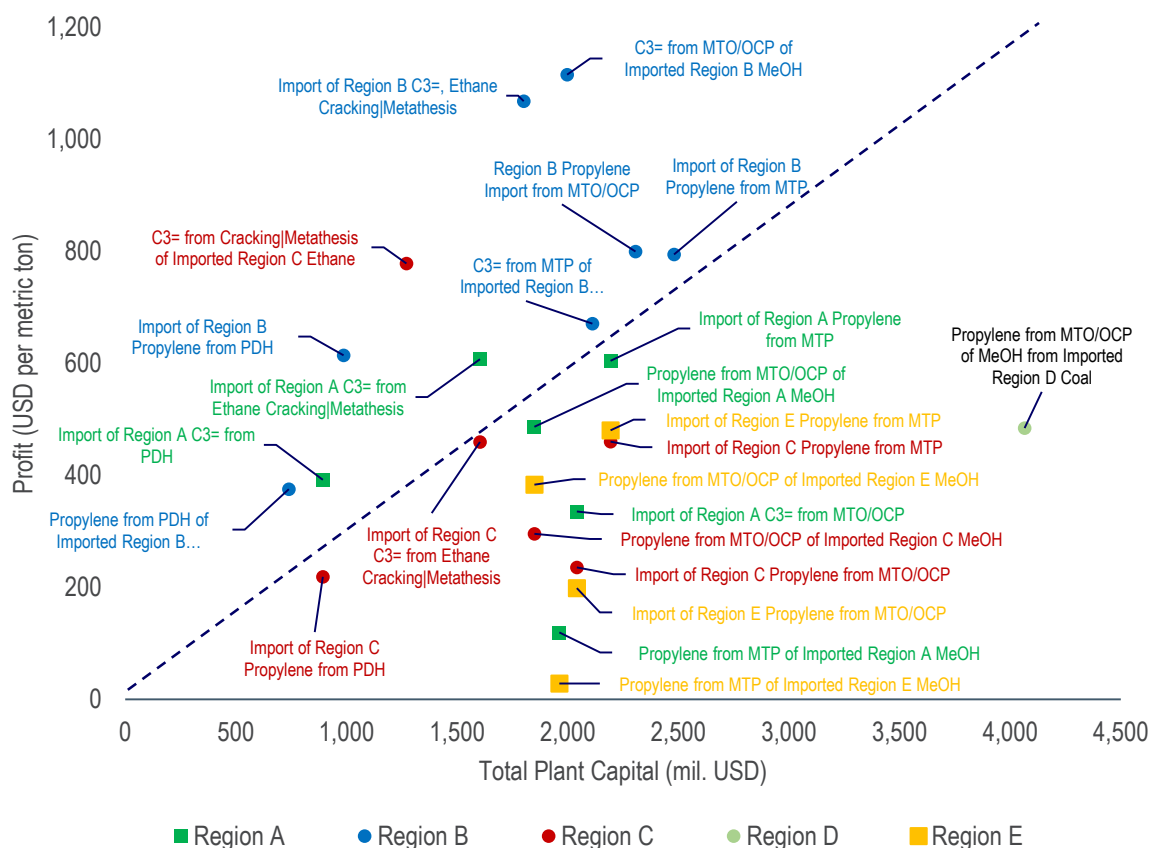
In addition to understanding the cost of production (COP) for each process, the report includes Nexant's analysis on how the COP varies between 2015 and 2030 for each oil price scenario. The figure below compares the COP for making polypropylene in Shanghai, China using nine of the leading process/region combinations from various imported raw materials from 2015 to 2030, with the high oil price scenario. Since the high oil scenario is the opposite of the 2015 scenario, we see that there are large changes in the COPs for some of the processes and regions, and small changes for other processes and regions. This helps the reader understand which processes are most sensitive to oil prices. The leading processes/regions for producing polypropylene are highly dependent on the oil price scenario in many cases, but less so in others.

Figure 2.5 Cost of Production for Polypropylene Production in Shanghai, China
(Nine low cost processes, High Oil Price Scenario)



The cost of production is also compared to the Total Plant Capital. The figure below compares polypropylene profitability in the High Oil Scenario Case in 2025 for five regions that are exporting either methane, ethane, propane, methanol, coal or propylene to Shanghai for production of the remaining value chain to produce polypropylene. The Total Plant Capital is the sum of the capital in the exporting region and Shanghai. This summary analysis ignores options that were found to be unprofitable. The report also provides a similar analysis of the profitability of exporting polypropylene made via various routes from each region to Shanghai for the low and medium oil price scenarios.

Figure 2.6 Polypropylene Profitability versus Total Plant Capital, Shanghai Production from Imported Raw Materials
(Profitable Configurations Only, High Oil Scenario, 2025)



Key Issues and Uncertainties

Among other issues, the economics of on-purpose propylene (compared to conventional propylene) depend on level of forward and backward integration and ability to profitably use or sell by-products such as ethylene, butylenes, gasoline and BTX. In addition, potential plant developers need to consider whether technology is commercially demonstrated, the number of licensors, and the expected capital cost in each region.

Conclusions

Unlike many competitive analyses, which are based on a snapshot in time, this study will use Nexant's best forecast models and critical thinking to predict which technology could be the low-cost process in 2020 and 2030 for each region, as well as on a delivered cost basis to Shanghai, China under three separate oil price scenarios.

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4.1 SUMMARY

Nexant during the course of its normal consulting activities maintains the following tools, methodologies and reports that are highly relevant to the topic of on-purpose propylene:

- **Global Gas Model:** 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.
- **Methanol Strategic Business Analysis:** This program, maintained by Nexant for over 15 years, rigorously evaluates technical and market developments for the global methanol industry. Reports are issued quarterly and annually to major industry participants
- **Process Economics and Research Planning:** This program tracks technical developments in all the chemicals that will be covered in this engagement. The program provides a detailed assessment of state-of-the-art technologies as well as capital and operating costs
- **Petroleum and Petrochemical Economics:** Nexant has provided this program for over 25 years. It evaluates the commercial outlook for all major petrochemicals, from ethylene, propylene, vinyls, styrenics and aromatics to all major derivatives including polyolefins (LDPE, LLDPE, HDPE, Polypropylene, etc.) and the major propylene derivatives
- **Polyolefin Planning Service:** This 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

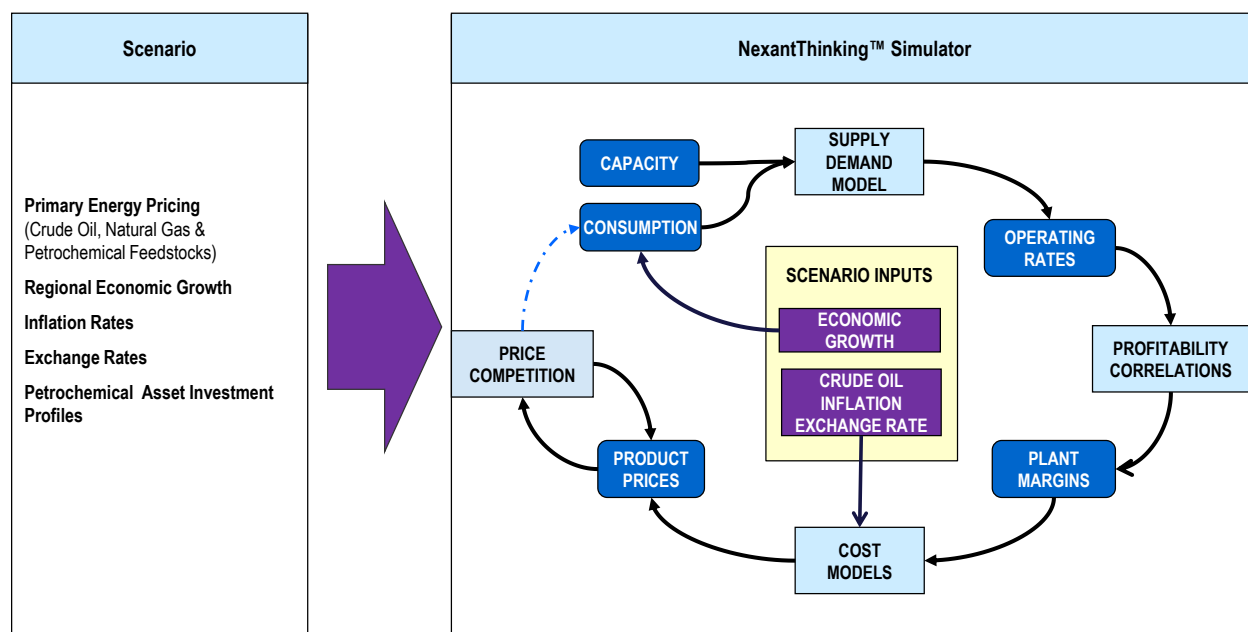
In addition to the above-mentioned programs, Nexant has performed numerous feasibility studies for the gas-based (methane to syngas, PDH), coal-based (coal to methanol), and methanol based (MTO/MTP) processes of interest. A detailed listing of our experience is provided in Section 6 of this prospectus.

4.2 NEXANT SIMULATOR

NexantThinking™ profitability and pricing forecasts are prepared using a proprietary simulation model of the global petrochemicals and petroleum industry. The advanced simulator is a fully integrated model of the global business dynamics (material flows and cash flows) using sophisticated software. The industry outlooks draw on more than 40 years of knowledge and experience of the global industry to develop algorithms to simulate petrochemical business dynamics. The NexantThinking™ petrochemical industry simulator is a unique offering, marking a major advance in supply/demand and profitability forecasting technology.

The NexantThinking™ forecast methodology relates market demand drivers to petrochemical consumption. From a database of petrochemical processes and plant capacity the regional consumption is compared to the ability to produce. Global trade algorithms complete a full supply, demand and trade model of the industry. Basic commodity theory dictates that market tightness, measured by average operating rates, is the primary driver of profitability. Production costs are built up from a detailed database of archetype plant techno-economic models, heavily influenced by the assumptions of crude oil prices. Petrochemical product prices are determined by adding projected production costs to the margin outlook. Inter-regional competition and inter-material competition add further constraints and complexity to shape the pricing dynamics.

Figure 4.1 NexantThinking™ Petrochemical Industry Simulator Forecast Methodology



4.3 GAS MARKET ANALYSIS

Nexant will utilize 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 natural gas as a feedstock for chemicals. The basic approach will consist 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 price projections under different scenarios
- 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.

The market analysis for this report will be 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 4.2. Nexant has used this modeling system to provide the underlying foundation for the market and pricing assessments presented in this report.

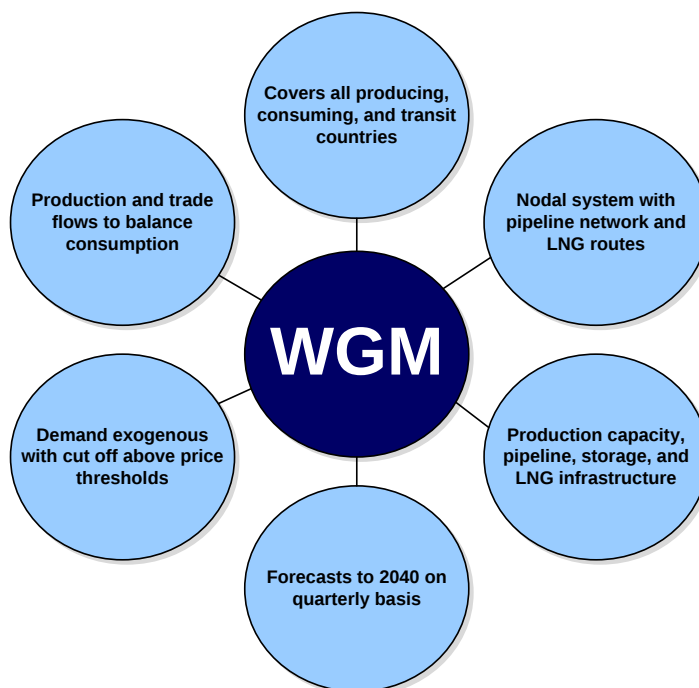
WGM uses a powerful optimizer program, in conjunction with Microsoft Excel, which allows all inputs and outputs to be analyzed by users and linked to other in-house systems. The model projects global, regional, and national gas supply demand balances, international gas trade by pipeline and LNG and both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

4.3.1 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.

Figure 4.2 World Gas Model



4.3.2 Cost Data and Gas Prices

Cost data is included for all facilities in the model including production, pipelines, liquefaction, and regasification terminals, storage facilities, and LNG shipping. Shipping costs are built up from shipping distances and assumed day rates and fuel costs.

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.

4.4 DELIVERED COST ANALYSIS

Nexant uses a standard pro-forma to calculate cash costs of production for methanol, ammonia, and urea. As indicated in the figure below, 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 direct fixed costs shown in the figure below include:

- Salaries of operating staff plus associated on-costs such as holiday cover, social insurance, fringe benefits etc.
- Maintenance costs including materials and labor, 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

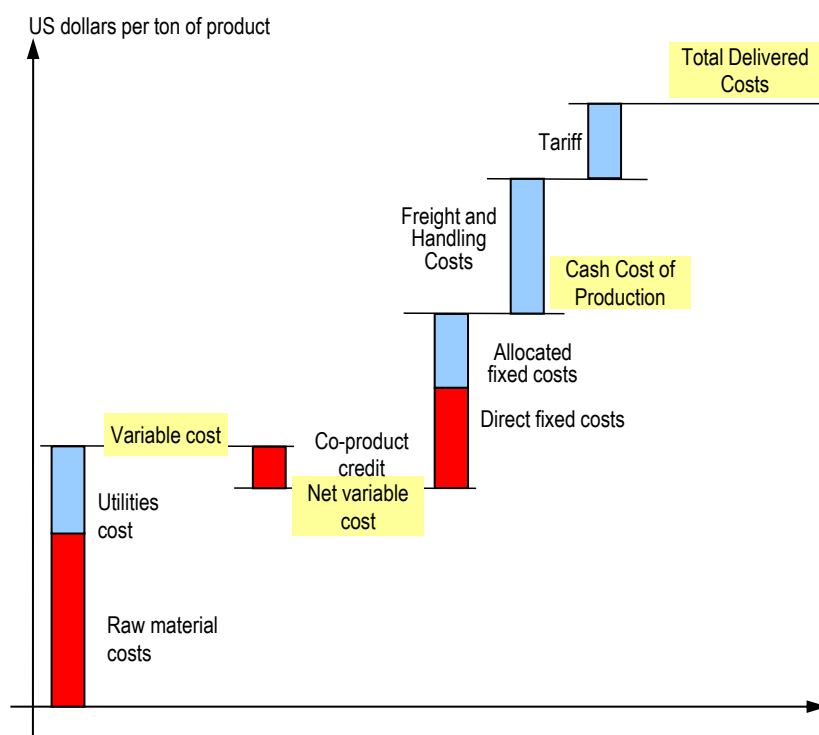
The allocated fixed costs are the site charges, which are necessary for production but which are not directly associated with the operation of the specified process plant. They include packing and warehousing,

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.

In addition to the derived total cash cost of production, Nexant takes into account the freight and handling costs as well as tariffs involved in delivering the product to a particular target market to calculate the total delivered cost.

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.

Figure 4.3 Components of Cost of Delivery to Market



4.4.1 Alternative Propylene Feedstock Prices: Crude Oil, Naphtha, Coal, Ethane, Propane, and Natural Gas

4.4.1.1 Crude Oil/Vacuum Gas Oil

For most chemicals, crude oil prices are the most critical underlying cost driver. The cost to run the FCCU is highly related to the cost of vacuum gas oil (VGO) and to crude oil. However, the price of propylene has a relatively minor impact on FCCU operating decisions, although it does impact alkylation economics and utilization.

Three major “marker” crude oils are commonly referenced by the petroleum industry: West Texas Intermediate (WTI), Dubai and Brent. Dubai is representative of medium heavy (higher API gravity) and sour (higher sulfur) crude oil, while Brent and WTI are representative of lighter sweeter (low sulfur) crude oil. Nexant utilizes Brent crude oil, on a FOB (free on board) basis, as its global marker crude oil as Brent prices are determined within the most liquid global markets less inclined to local pricing distortions.

Recent developments in crude oil markets have shown the difficulties of accurately forecasting prices. Crude oil prices increased to a record high approaching \$140 per barrel in the middle of 2008 before the global economic recession depressed prices almost two thirds by the end of the year. Prices swiftly

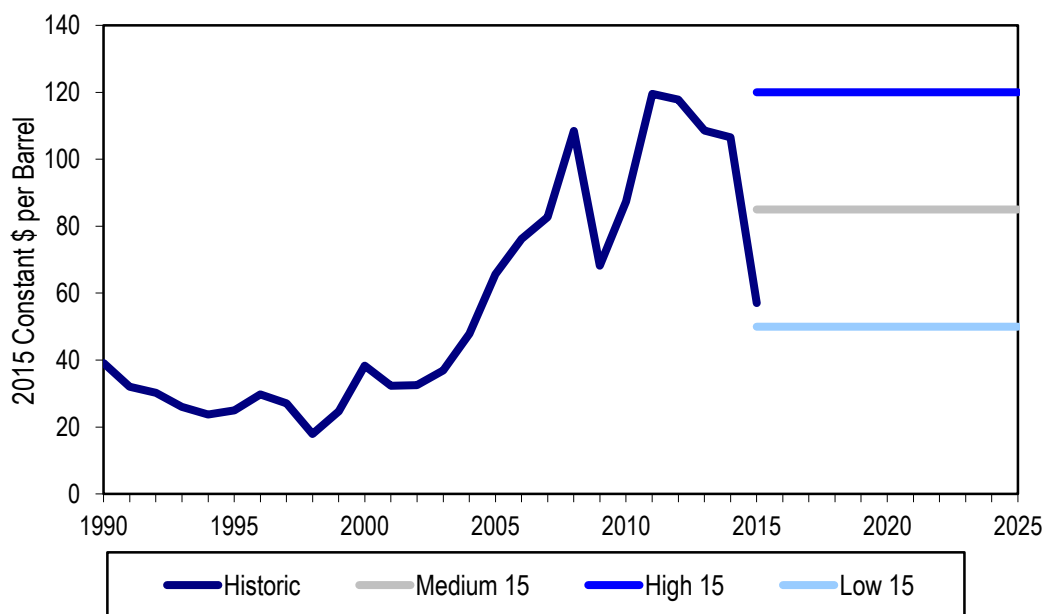
recovered in 2009 despite fragile growth in many Western economies. Crude oil prices climbed back above \$100 per barrel in 2011 and continued to be around this level through the first half of 2014, as mounting fears that political instability could disrupt supplies from the Middle East. Growing uncertainty in the strength of global economic activity has amplified volatility in crude oil prices as leading economic indicators swiftly adjust market sentiment. In the second half of 2014, as growing supplies of shale oil from the U.S. displaced crude oil imports, OPEC (and in particular, Saudi Arabia) decided to abdicate its historic role of managing crude oil prices by constraining or expanding supply. As a result, crude oil experienced extreme volatility and declined by over 50 percent, leading to a rapid fall in the prices for naphtha, other cracker feedstocks, ethylene, and cracker co-products.

Nexant considers that the current rapid weakening in oil price is a normal market effect, and that such weakness in oil prices can be expected to occur below “average long term” pricing levels. Such weakening and subsequent rebounds at varying scales have occurred historically. Nexant maintains that its Medium Oil price is a reasonable pricing environment to evaluate the likely future economic performance of a project and remains a robust basis for Lenders to understand the performance of a project. However, Lenders and project sponsors are also advised to consider the economic performance in alternative Low and High crude oil cases, and in particular to evaluate the impact of a short duration (1-3 year) deviation of oil prices on cash flow for their project.

Nexant has prepared three distinct scenarios for 2015, spanning a broad range of crude oil prices that is reasonably expected to capture the range of future pricing in most years. The crude oil prices selected for Nexant’s 2015 scenarios (Brent FOB basis) are:

- **High oil scenario:** set at \$120 per barrel (2015 constant dollars)
- **Medium oil scenario:** set at \$85 per barrel (2015 constant dollars)
- **Low oil scenario:** set at \$50 per barrel (2015 constant dollars)

Figure 4.4 Crude Oil Price Scenarios
(Brent crude oil, FOB Sullom Voe)



The high, medium and low scenarios assume that crude oil prices are steady in real terms, capturing at least two underlying pricing influences. Firstly, reductions in costs are anticipated through continued technology improvements in exploration and production activities. This experience curve effect reflects trends in other commodities, which show reductions in real prices due to gains in production efficiency. Secondly, the view is taken that future marginal production will come from more remote and demanding fields with a higher cost base. Based on production cost curve analysis, it is highly unlikely that long-term prices of oil can remain below \$70 on a constant dollar basis.

Since crude oil is the source of the high-boiling long-chain alkanes (VGO) that are the feedstock to the FCC unit, it is a potential driver of propylene cost analysis.

4.4.1.2 Naphtha

Light naphtha, with a boiling range up to around 90 °C, typically has high paraffin content and is used as a feedstock for steam crackers in Asia and Europe. As was previously mentioned, the Middle East and increasingly North America crack lighter feedstocks based on NGLs. Heavier naphtha streams are typically used as feedstock for catalytic reforming to manufacture aromatics and reformat a high-octane blendstock for motor gasoline.

The prices of U.S. Gulf Coast naphtha streams are closely linked to Gulf Coast gasoline prices since most of the region's naphtha and natural gasoline is used to produce gasoline. Light Virgin Naphtha (LVN) prices usually reflect its value as a gasoline blendstock, taking into accounts its relatively low octane and high vapor pressure. Shale oil sources in the Eagle Ford and Bakken region produce oil with a high proportion of light naphtha compared to WTI, which (combined with the shift to lighter cracker feedstocks) has somewhat shifted the supply demand balance and led to lower naphtha values. Nexant's forecast of naphtha prices is based on these drivers, which are offset by the availability and price of high octane feedstock.

4.4.1.3 Natural Gas/Methane

Natural gas is widely used in the chemical and petrochemical industries around the world both as a provider of energy to fuel the chemical processes and also as a raw material feedstock for conversion into chemicals for further processing. Natural gas prices are influenced by the value of competing fuels and the global dynamics of gas markets. The result of the new developments in feedstock availability from shale gas in North America has been a significant increase in the competitiveness of United States petrochemical manufacturers in global markets. Simultaneously, the relatively low prices in the U.S. had led to numerous applications for export permits as well renewed interest in natural gas as a transport fuel. While the combination of these new demand sources should tighten supply and demand over the coming decades, the United States will remain an advantaged place to produce methane based chemicals such as methanol and ammonia, at least partially reversing years of imports. As LNG prices are typically linked to crude oil prices, the recent decline in crude oil has resulted in a marked decline in LNG prices.

As described in more detail in Section 4 of this prospectus, Nexant tracks natural gas supply and demand with its World Gas Model (WGM), which is Nexant's proprietary model for supply, demand, trade, infrastructure utilization, and price projections under different oil price scenarios.

4.4.1.4 Natural Gas Liquids

Ethane, propane, and butane produced by extraction from natural gas are known as natural gas liquids (NGL). The United States currently operates approximately two thirds of its steam cracker production capacity based on NGL feeds. Ethane pricing, due to its exclusive use as a petrochemical feedstock, is highly dependent on the prices of competing petrochemical feedstocks as well as the price of natural gas from which it is extracted.

In contrast, market prices for propane, butanes, and natural gasoline generally are relatively insensitive to the value of the natural gas from which they are extracted. Rather, their prices are influenced by competition with crude oil-derived products in markets where they compete as alternative fuels or petrochemical feedstocks. Therefore, ethylene price and steam cracker economics have a major impact on NGL pricing.

Ethane

The only significant use for ethane is as a steam cracker feedstock for the production of ethylene. Approximately 70 percent of the ethylene produced in the United States is derived from ethane and ethane/propane cracking. Ethane produced in oil refining is generally consumed as a fuel gas within the refinery.

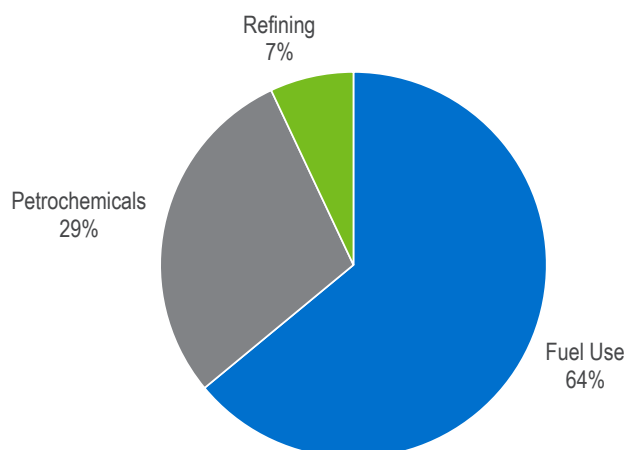
The factors that influence ethane pricing are:

- Its value to a steam cracker operator
- The cost of intentionally extracting it from natural gas

Ultimately, the ethane market price is established by the supply/demand balance. The gas plant operator controls the supply based on how much ethane can be extracted economically, and the ethylene plant operator controls the demand based on how much ethane can be cracked at a lower net variable cost than that achievable with alternative cracker feedstocks. Currently, the shale gas boom has led to considerable “ethane rejection”, where some ethane is left in the natural gas rather than extracted for use as cracker feedstock. In fact, until the multiple new crackers are operational, ethane rejection will continue to grow for the next several years. This excess of U.S. ethane has led several ethylene producers in Europe and now India (Reliance) and other regions to announce plans to modify their crackers and import ethane as a feedstock. In addition to possible modification of their crackers, this change will require new terminals, ships, and infrastructure, so it will take some time before ethane exports has a significant impact on ethane rejection dynamics and ethane pricing.

Propane

Similar to natural gas, propane and LPG are largely used as fuel for residential and commercial applications, but are also used as feedstock for steam crackers and for refinery applications. In addition, as the steam crackers switch to lighter feedstocks, growing amounts of pure propane (for PDH) and iso-butane are used as feedstock for dehydrogenation units. Historically, global propane prices have tracked naphtha prices most closely, moving in a narrow band of 10 percent either side of the naphtha price, on a mass basis. More recently, however, prices in the United States have weakened relative to the price of naphtha and competing fuels and new shale gas supplies have led to growing propane exports from the United States, and lower propane prices compared to other regions. The expansion of the Panama Canal will open access to East Asian markets as the shipping time from the U.S. Gulf Coast to Japan will be reduced from 45 days to 25 days and further drive propane exports from the United States. Additionally, the price differential between the United States and Middle East will encourage East Asian consumers to look to U.S. supplies not only as a low cost option, but also as a prospect for diversification of supplies.

Figure 4.5 World LPG Demand by Sector

As a result, new export terminals are under construction, and North America is expected to join the Middle East and Africa as key sources of LPG supply to Asia/Pacific. Japanese, Chinese and South Korean firms have already signed term supply deals for U.S. Gulf Coast supply. Exports to Europe are also expected to increase with the lower freight rate resulting in some competition for spot exports between Europe and Asia. These exports of propane are expected to be the swing outlet for propane from gas plants, and as the marginal source of demand, directly affect the price setting mechanism for propane in the United States. *If the price of propane becomes dependent on export parity economics, the equilibrium price of propane will impact the economics of the planned PDH capacity in both China and the United States.*

4.4.1.5 Coal Price in China

Under a normal market economy, the price of coal is mainly dictated by its heating value and market demand and supply, as well as any environmental burdens placed on its consumption. Driven by domestic demand for energy and supported by China's macroeconomic control policy, the coal economy began to recover from late 2000, with increasing coal demand and rising coal prices. Coal in China now has large volumes going to heavy industry applications such as steel and power generation, plus home heating. However, with the current economic slow-down and the push for more renewable power, many coal mines in the central region have looked for way to convert the carbon in coal into chemicals.

4.5 COSTING BASIS

The cost analyses cover the cost of production at the plant gate and exclude the following:

- Feedstock acquisition and trading costs
- Distribution, selling, and marketing costs
- Research and development (R&D) costs
- Corporate (or head office) overhead costs
- Interest on capital cost financing and other financing related charges

The methodology used to develop the cost estimates is briefly summarized below, while Appendix A and B describe more fully the capital cost and operating cost elements that will be encountered in the cost of production tables given later in this section.

4.5.1 Investment and Pricing Basis

A process plant can be viewed as consisting of two types of facilities. The first is the manufacturing area containing all process equipment needed to convert the raw materials into the product. The capital costs

of these facilities are commonly referred to as the inside battery limits (ISBL). The second group of facilities contains the outside battery limits (OSBL) or offsites. These include general utilities (e.g., instrument and utility air, nitrogen, fire water, etc.), administrative buildings, steam generation facilities, cooling water system, electrical distribution systems, waste disposal facilities, etc.

For all the cases considered, investment costs assume “instantaneous” construction or implementation in the designated year. This is a simplification because initiation, design, and construction can take several years to complete. In order to undertake the instantaneous analysis, phased investment costs and associated financial charges are consolidated into a single overall project cost.

In addition to the plant capital, the owner usually has other costs associated with the project such as project management, startup, etc. Working capital is calculated to reflect raw material, byproduct, and supplies inventories; accounts receivable; cash requirements etc., with credit for accounts payable.

Propylene capacity is a nominal 500 kta for each technology evaluated up to the world class scale limit. Capital costs are estimated for the “instantaneous” investment in the first quarter of 2015 and the estimated cost of production will be provided for 2015, 2020, 2025, and 2030 for the three separate oil price scenarios. Most prices and operating costs are from Nexant’s internal databases and established third party pricing sources, while a few values have been obtained from industry contacts.

- **Marcos Nogueira Cesar – Project Executive** - Marcos is Global Vice President, Products in Nexant and will act as Project Executive. Mr. Cesar has over 20 years of experience in market and economic evaluation, technology assessment and competitive analysis in both consulting and industrial environments. He currently manages the global multi-client and subscription products business of Nexant's consulting operation, which provides analytics, forecasts, and insights for the chemical and energy industries. Prior to joining Nexant in 2013, he was Vice President of Chemical Industry Research and Senior Director, Global Product Management at IHS, where he led the integration of the entire IHS Chemical portfolio of multi-client products and services (legacy SRIC, CMAI, Harriman Chemsult and Chemical Week). He previously served as Global Director of Business Development and Vice President, Latin American Operations at SRI Consulting. Mr. Cesar was a Fulbright Scholar. He started his career at Rhodia S.A. and holds an M.B.A. from the University of California at Berkeley, an M.S. in Chemical Engineering at the University of Massachusetts at Amherst, and a B.S. in Chemical Engineering at the State University of Campinas (Brazil). He is fluent in English, Portuguese, Spanish, and French
- **Randy Rabenhorst – Project Manager** - The engagement will be under the overall direction of Randy Rabenhorst who is a Principal in Nexant's Energy and Chemicals Consulting Practice in White Plains, NY. He has been a consultant to the chemicals, plastics, and specialty chemicals industries for over 25 years, with notable experience in market dynamics and pricing for olefins, polyolefins, aromatics, foamed polymers, fracking chemicals and organo-metallics. Areas of interest include development of: strategies for growth and profitability, competitive assessments, value-chain assessments, product and market positioning, and acquisition valuations. Prior to his role as a management consultant, Mr. Rabenhorst held various management positions in marketing, finance, and sales for Chemical Waste Management and BF Goodrich. He holds an M.B.A. from The Wharton School, University of Pennsylvania, as well as an M.S. in Chemical Engineering from the University of Maryland
- **John Boepple – Ethane and Propane Price Forecasts** - Mr. Boepple is a Vice President in Nexant's White Plains, NY office with over 35 years of experience in international petroleum product pricing & markets, and refinery operations in a broad range of consulting assignments relating to the gas processing and refining industries in the Americas, Asia and other regions. He has extensive international experience in evaluating a broad range of technical, economic, commercial and strategic issues related to the use and pricing of NGL, LPG and other petroleum products. Specific areas of expertise include: crude oil, LPG and refined product pricing at all levels of the value chain, transportation and logistics related to crude oil, LPG and refined products and economic and technical evaluation of refinery processes. His experience includes managing a project to develop an implementation plan to promote the use of LPG as a vehicle fuel in Argentina during which he analyzed the economics of LPG compared to gasoline, diesel and CNG for various market sectors. John holds a B.S. Chemical Engineering from Cornell University as well as a M.S. in Chemical Engineering from the Massachusetts Institute of Technology
- **Mike Fulwood – Gas Market Forecasts** - Mike is a Principal in Nexant's Global Gas practice. He has over 30 years of experience in the energy industry. Before working as Director at British Gas Transco, Mr. Fulwood was President of British Gas Americas and led a high-caliber team responsible for developing downstream gas projects and investments in North and South America. He was also responsible for several successful acquisitions

Mr. Fulwood has been lead advisor to governments, and international energy and utility companies on acquisitions, project development, and regulatory matters. He has advised Clients in the Asia Pacific and Atlantic Basin regions plan the development of gas supply projects and led a high profile

assignment on international gas markets and gas pricing for the Gas Exporting Countries Forum. He is a current UK member of the International Gas Union's Strategy, Economics and Regulation Committee, and Chairman of the Gas Pricing Sub-Group

- **Brian Little – Gas Market Forecasts** - Brian is a Principal in Nexant's Global Gas practice. He has over 35 years of experience in the energy industry, including 10 years in consultancy, and over 25 years working for British Gas. His areas of expertise include all aspects of market analysis, modeling, forecasting, pricing, and benchmarking. He has overseen the development of Nexant's World Gas Model

Mr. Little has provided advice to clients all over the world on gas markets and pricing and was responsible for the gas market modeling and pricing analysis on an assignment on international gas markets and gas pricing for the Gas Exporting Countries Forum. The project included reviewing trends in gas markets, regulation, and inter-fuel competition

- **Andrew Powell – Chemicals Price Forecasts** - Mr. Powell is a Project Manager in Nexant's London office and has over 20 years of industry experience. Lead role in development of Nexant's petrochemical industry simulator which allows clients to forecast market dynamics, industry profitability and prices under multiple global economic scenarios. Regular analysis of global industry profitability and regional trends through researching and running profitability models used as base of Nexant's Quarterly Business Analysis (QBA). QBA is a quarterly review of current industry costs, prices and margins for commodity petrochemicals in main global markets. Andy is a major contribution to development of Nexant's petrochemical profitability and price forecasts including identification and development of appropriate price setting mechanisms and pricing trends. Andy holds a Eng (Hons) 1st Class Chemical Engineering from the University of Cambridge as well as a MSc Engineering Business Management from the University of Warwick
- **Donnie Wickham - Chemicals/Market Economic Analysis** - Mr. Wickham is a Consultant in Nexant's White Plains office. He has gained substantial experience in performing feasibility studies for several major global manufacturers of both petrochemical and biochemical derivatives. He is versed in due diligence evaluations of prospective merger and acquisition targets, as well as financial modeling, cost of production modeling, and market dynamics analysis geared towards furthering producer competitiveness. In recent years, Mr. Wickham has also assumed an advisory role as independent engineer for multiple major chemical projects looking to obtain financial backing from potential investors. Mr. Wickham has also conducted studies that analyzed both the natural gas market and the demand for ammonia, urea and derivative fertilizers, in addition to developing business strategies that aim to assist manufacturers looking to enter into the markets for such products. Donnie Wickham received a BSc in Chemistry from Morehouse College and a BE in Chemical Engineering from The City College of New York.

6.1 OVERVIEW

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 6.1.

Figure 6.1 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 Southeast Asia.

Major annual subscription programs are:

- Process Evaluation/Research Planning (PERP)
- Petroleum & Petrochemical Economics (PPE) – United States, Western Europe, Middle East 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.

6.1.1 Process Evaluation/Research Planning (PERP)

The PERP program provides valuable insights and information to research planning and marketing personnel. It examines existing, developing and embryonic technologies, aiming to provide early identification of commercially significant technical developments. Ten or more reports per year are on petrochemicals; additional reports cover polymers, fine and performance chemicals, and other topics.

Recent PERP topics relating specifically to methanol and its derivatives have included:

- Methanol
- Developments in Methanol Production Technology
- Methanol to Olefins
- Developments in Syngas Production

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.

6.2 GLOBAL NATURAL GAS EXPERTISE

Nexant's gas specialists have considerable experience and an established track record in every area of the gas business, ranging from the initial investment strategy, and planning stage through to the provision of institution and capacity building services for gas sector development, as well as assessing the impact of natural gas on overall energy sector development. Nexant has provided extensive advisory support for the development of natural gas export/import projects, LNG markets, gas to power projects, and cross-border gas pipeline projects.

Nexant assigns expert multi-disciplinary teams who can provide a broad range of services and draw on the resources of Nexant's other sectors of expertise, such as power, petrochemicals, liquid petroleum products, clean energy, and energy technology, to deliver integrated energy solutions.

Its consultants offer a wide range of experience that has been gained through operational and management positions with international and national oil & gas companies; major engineering companies; management consultancies and international development banks.

Nexant's range of services includes:

Market Analysis

- Market analysis and forecasts, supported by Nexant's proprietary World Gas Model, including gas supply and demand, LNG, and gas pipeline trade flows, and wholesale gas prices
- Gas market studies covering the full value chain, for countries and regions, as well as studies focusing on markets for new or incremental LNG and gas pipeline supplies

Advisory Services

- Advisory services on gas business strategies, gas project development, contractual arrangements and mergers and acquisitions
- Commercial analysis of projects, including due diligence services on new gas investment projects

Market Development

- Studies supporting gas market development in emerging gas markets, including gas monetization studies and gas master plans
- Development of gas regulatory frameworks, gas pricing mechanisms, and transportation tariff studies
- Economic and financial evaluations of gas projects for bilateral and multilateral development agencies
- Pre-feasibility studies to develop LNG and gas pipeline infrastructure projects

Nexant's consulting services cover all areas of the natural gas business and its Global Gas team is excellently qualified to assist on assignments throughout the gas chain.

6.2.1 Specific Experience Relevant To Shale Gas

Nexant is exceptionally qualified to perform this study's comprehensive analysis based on our multidisciplinary business approach and having carried out studies of this type throughout our more than 45-year history. The knowledge and experience gained from these engagements will provide an invaluable basis for Nexant to successfully address the objectives of the study.

A partial list of projects relevant to North American shale gas includes:

- **Frac Services – North America:** For a major industrial gas company, Nexant identified U.S. gas fields that have extensively applied hydraulic fracturing technologies. The engagement included identifying and quantifying shale gas resources in the selected geographies, and characterizing

existing and proposed technologies to develop these resources while providing alternatives to hydraulic fracturing. Nexant also included an analysis of breakeven gas prices that make the technology attractive, as well as identified and assessed public policy issues that bear on the development of shale gas resources in the selected geographies

- **U.S. Shale Gas and LNG Exports – USA:** For a private equity firm, Nexant analyzed the supply curves for natural gas production in the Lower 48 U.S. States, with particular reference to shale gas, the cost of LNG exports from the U.S. Gulf Coast to key markets and projections of Lower 48 natural gas production. In particular, it analyzed: Cost of production of shale gas over time; Cost of LNG exports to five key markets: UK, Spain, Japan, China and India

Projections of Lower 48 natural gas production to 2030, categorized into associated, shale, coal bed methane, conventional and offshore

- **North American Shale Gas and Shale Oil Research** – Nexant reviewed and analyzed North America's nascent shale oil and shale gas business. Nexant examined current and projected shale oil and shale gas production levels on a play-by-play basis; reviewed the various technical and regulatory challenges faced by shale players in North America; discussed the implications of shale gas production for the U.S. petrochemical sector; and evaluated North America's multiple shale gas-based export plans
- **Unconventional Natural Gas** – This report reviewed key aspects relating to the development of unconventional natural gas resources. Technological and operational challenges, reservoir characteristics, production behavior and environmental concerns, commercial drivers (cost and breakeven economics), new developments (technology and designs), worldwide occurrence (in place resources and recoverable reserves), and the long term view (production and consumption scenarios) were discussed

NGL Extraction Technologies – This PERP report provides a review of the commercially available technology options that are available for the extraction of natural gas liquids from natural gas streams, while also looking at the future trends in technology development. The report also explores the economics of NGL extraction, while giving an overview of key NGL markets.

6.2.2 Specific Experience Relative to Natural Gas as a Feedstock

Nexant has extensive experience in the area of GTL technology: syngas generation, F-T synthesis, and F-T product upgrade. Nexant's Process Evaluation/Research Planning (PERP) Program has carried out, on a routine basis, the assessments of the competitive economics of the technologies for GTL, syngas, methanol, DME, etc.

Nexant has also completed the following multi-client special topical reports that have enjoyed a wide circulation in the GTL industry:

- Stranded Gas Utilization – Steps to Commercialization
- Stranded Gas Utilization -- Methane Refineries of the Future
- Alkane Activation – Petrochemical Feedstocks of the Future
- Adding Value to Methane – Strategic Opportunities for the Middle East

Nexant has also been engaged in numerous single-client consulting projects for the technology and market evaluations of the following commercial and developing GTL technologies:

- BP
- ConocoPhillips
- ExxonMobil AGC-21
- PetroSA/Statoil

- Rentech
- Sasol SSPD
- Shell SMDS
- Syntroleum

Throughout our single client and multi-client studies, we have reviewed each licensor' offering packages and evaluated each licensor' patent positions.

Our technology evaluations have included process design review, comparison to competing technologies, capital cost and cost of production estimates, and sensitivities regarding attainable process and cost improvements.

6.2.3 Selected Project Experience in GTL

- **Ultra Clean Fuels Study-** Under U.S. DOE funding, Nexant teams with Conoco and Pennsylvania State University to evaluate several alternate ultra clean fuels, such as GTL liquids and methanol. The main objective is to perform comprehensive life cycle analyses and a market study on ultra clean fuels of commercial interest produced from natural gas. The life cycle analysis will examine the energy use, emissions, solid wastes and wastewater for complete fuels systems for both transportation and power generation. The market study includes a detailed analysis of the U.S. refining market. The five U.S. refining market regions (Petroleum Administration for Defense Districts (PADDs) will be modeled on PIMS, a linear programming software, to identify and accurately quantify the impacts of introducing the ultra-clean fuels to the market, both neat and blended with existing refinery streams. The market study encompasses all U.S. activity from present through future regulatory changes up to 2015
- **Alternate Fuels and Chemicals from Synthesis Gas-** As a subcontractor to Air Products and Chemicals, Inc., Nexant's specialists evaluated the feasibility of the new liquid-phase technologies based upon Fischer-Tropsch and other synthesis gas reactions to efficiently produce alternative fuels and chemicals. The program targets the development of liquid-phase technology for the synthesis of oxygenates, cheaper routes to MTBE, mixed ethers, higher alcohols, olefins, acetyls, methyl formate, and premium hydrocarbons via Fischer-Tropsch chemistry
- **Technical Review of GTL (Confidential)-** Nexant performed an engagement to provide an independent third party review and analysis of a process design and scale up program for GTL technology, developed by a major energy company, covering process risks and recommendations on how the risks could be mitigated in the commercial plant design
- **Syntroleum Corporation-** Nexant performed an independent market study for specialty hydrocarbon products to be produced from a planned GTL project. Nexant' analysis included an analysis of historical and recent product pricing, analysis of alternative costs of supply for these specialty products, forecasts of supply and demand for the products, consideration of product quality and regulatory trends, and product price differentials relative to more commodity products
- **New Zealand Gas-to-Gasoline Project-** The Gas-to-Gasoline (GTG) facility was designed to produce 14,500 bpsd of high quality gasoline from 140 mmscfd of natural gas. The plant uses conventional ICI low-pressure methanol technology to convert natural gas to methanol in a fixed bed reactor. The methanol is then converted to gasoline in the fixed bed multi-reactor MTG process developed by Mobil Research and Development. The gasoline is hydro-treated to produce a high quality gasoline product. The facility was stand-alone and included essentially all the utilities and offsite support plants necessary to be self-sufficient. Nexant personnel were the main contractor and performed the engineering on the majority of the plants. Valuable experience was gained in the integration of a first-of-a-kind project like this to achieve a reliable and operable plant

- **JOGMEC** - New GTL Technology Development, Product Upgrading Design, Process Evaluation and Benchmarking, Economic Assessment and Commercial Analysis (Confidential)
- **PetroSA GTL** - Scale-Up Risk Assessment and Mitigation (Confidential)
- **Statoil GTL** - Technology Assessment (Confidential) Methanol

6.3 METHANOL

Nexant has performed **well in excess of one hundred engagements** concerning methanol business or project evaluations in all parts of the globe. It has developed considerable intellectual capital including market dynamics, pricing and profitability and technology databases, which is used as a basis for its consultancy services. The types of consultancy services provided to the sector include:

- Strategic Planning
- Project Planning/Evaluation/Development Assistance
- Technical and commercial feasibility studies to support decision-making and project financing
- Technology selection and evaluation
- Market evaluations including addressable market appraisal
- Independent technical and business due diligence to support financial transactions
- Process and business benchmarking and optimization studies
- Efficiency enhancement assistance.

As methanol is a core sector for Nexant, it publishes multi-client reports led by its flagship Strategic Business Analysis (SBA) program. It also includes methanol and its derivatives in its list of products that are reviewed in its Process Evaluation and Research Planning (PERP) technology program.

The following list indicates the extent of recent experience in the business of methanol. Other studies, not listed, cover methanol derivatives including formaldehyde, MTBE and acetyls (acetic acid and VAM), DME and biodiesel, and ethanol, and related topics such as oxygenates, the gasoline market, natural gas pricing, butane pricing and refinery optimization. In addition Nexant has performed many studies on the markets, technologies and production economics for other methanol derivatives including: dimethyl terephthalate (DMT), methyl methacrylate, methylamines and DMF, solvents, dimethyl carbonate (DMC), methanol to olefins (MTO) and methanol to propylene (MTP) etc. In many cases, the nature of our work is confidential and we are not free to identify the client with the project. For this reason, some of the projects listed below do not identify the client.

6.3.1 Natural Gas Utilization for Methanol Production

- **Natural Gas Utilization** - A natural gas utilization study for Argentina, including: Gasoline octane enhancement preliminary licensor information, MTBE production and use pre-feasibility study; Economics, pricing and project financing; Study of the optimum use of natural gas in transport
- **Natural Gas, Methanol & Fertilizer Strategy Plan Development** - The development of a 10-year strategic plan for margin enhancement for a major Russian chemicals and fertilizer company whose portfolio includes four methanol plants, incorporating conventional natural gas reforming and also acetylene off-gas technologies. The strategy was based on technology and manufacturing assessments of the sites, market characterization and a profitability assessment of each business versus the wider global industry. Businesses and projects were identified within the substantial portfolio for expansion/investment and others for exit
- **Natural Gas, Methanol & Ammonia Feasibility Study Assessment and Ranking** - An Asian national oil and gas company was seeking new domestic investment opportunities to add value to

its natural gas resources. It had received a number of project proposals from global companies in the form of detailed feasibility studies for methanol and/or ammonia production. The company retained Nexant to carry out an independent due diligence of these studies and to recommend investment priorities. Nexant undertook market opportunity studies, price forecasts, financial modeling, and other project assessments, and rated and ranked the projects

- **Natural Gas & Methanol Techno-Economic Feasibility Study** - An evaluation of current and prospective large-scale technologies, capital and operating costs for a Qatari client considering investing in a large-scale methanol project. A financial evaluation of the project was performed and various sensitivity cases considered. Project development and implementation strategy was also reviewed
- **Methanol Project – Trinidad** - Retained by Citicorp to provide project finance-related consulting services for the Caribbean Methanol Company's plant at Point Lisa's, Trinidad with input focused on the following: Review of lump-sum turn-key (LSTK) contractor services; Participation in contract negotiations to complete the contractor LSTK agreements and the product offtake agreements
- **Indonesian Methanol Project** - Consulting assistance to evaluate the East Asian and U.S. methanol markets, including a competitor analysis focusing on existing methanol plants in the Asian region, the U.S. Gulf Coast and other major exporting regions for a client considering a natural gas based methanol project in Indonesia
- **Market Feasibility Study, Russia** - Nexant reviewed methanol, ammonia and urea markets, pricing, delivered cost competitiveness, market entry strategy and technology options for a potential new entrant

6.3.2 Other Methanol Studies

- **Methanol Competitiveness and Business Valuation Study** - A comparison of the production economics of a major methanol producer with its major competitors and then a valuation of the business based on a forecast of its methanol margin
- **Methanol Production Economics** - An economic evaluation of the costs of methanol production for a major gas utility
- **Methanol Technology** - An update on methanol technology for a European chemical major
- **Methanol Technology Analysis** - A methanol technology analysis for an American oil company
- **Methanol/MTBE Price Projections** - Methanol/MTBE price projections for a Middle Eastern project for the banking consortium
- **Evaluation of Methanol Sourcing Options** - An evaluation of methanol sourcing options for a Latin American Oil Company
- **Methanol Market and Competitor Analysis** - A methanol market and competitor analysis for an Indonesian company considering a new project
- **The U.S. Methanol Industry** - An analysis of the historical and future U.S. methanol industry for a potential purchaser of a major U.S. methanol facility
- **Methanol from Biomass** - An assessment of cost of production of methanol from biomass for the Solar Energy Research Institute - SERI
- **Methanol Market Review/Forecast** - A methanol market study for the Heidrun Unit (DuPont/Conoco, Statoil, Arco, Norsk Hydro), with subsequent update for presentation to the Norwegian Parliament
- **Methanol Market and Technical Due Diligence** - Assistance to venture capitalists supporting the acquisition of a methanol producer. Activities included assessing the status of the plant and providing price and market forecasts

- **Methanol Plant Technical Review** - A review of a producer's gas consumption against that when the plant was originally built and the state of the art to assess the scope for future improvements and to identify the disadvantage compared to new world-scale plants
- **Methanol Benchmarking Study** - A technical review of the operating performance of a group of methanol producers, identifying the most significant factors responsible for below average plant availability and output
- **The Prospects for Diesel/Methanol Emulsions** - An assessment of the potential for methanol use, as an emulsion in diesel, considering the global use of diesel, the possible impact on refiners, etc.
- **U.S. Methanol Price Forecast** - A global methanol market and U.S. price forecast for a potential methanol producer
- **Crude Methanol Markets** - An analysis of the technical feasibility of selling crude methanol into chemical grade methanol markets for a potential methanol producer
- **Short Term Methanol Analysis** - An analysis of the global methanol business, in light of 1994 developments in the U.S. CAA implementation, for a major international oil company
- **Methanex Due Diligence** - A study relating to the re-financing of Methanex Corporation. This included a technical review of the operations of Methanex's Waitara Valley and Motunui plants in New Zealand, Cabo Negro plant in Chile, Kitimat plant in British Columbia, Canada and a review of the status and estimated cost and schedule for completing the Fortier Methanol joint venture in Westvaco, Louisiana
- **Methanol Market and Pricing** - A review of the likely growth in demand for methanol and a price forecast on behalf of an existing small methanol producer contemplating a major expansion
- **Methanol Business Opportunity Study** - A detailed study for a would-be methanol producer detailing methanol markets and pricing mechanisms as well as a forecast of the producers likely competitive position in the major global markets
- **Methanol Feasibility Study** - Nexant has recently completed a feasibility study for a 5 000 ton per day methanol unit in the PARS economic zone, Assaluyeh, Iran, for a foreign investor. This included market dynamics, price forecasts, cost competitiveness, marketing strategy, project execution and implementation definition and economic evaluation
- **Methanol Markets and Pricing** - Nexant was retained by Europe's leading methanol producer to analyze historic market and pricing trends and develop future projections, with a special focus on the European market
- **Market and Pricing Projections** - Market dynamics and pricing were reviewed and projected for methanol, formaldehyde, urea, melamine, amino resins, UF85, hexamine, and paraformaldehyde
- **Methanol Feasibility Study** - Analysis of markets, pricing, delivered cost competitiveness, technology selection and financial attractiveness of a large scale project in Iran
- **Methanol Feasibility Study** - Assessment of markets, pricing, delivered cost competitiveness, technology selection and financial attractiveness of a large scale project in Egypt
- **Methanol Market Study** - In this study for an acetic acid producer, historic and projected methanol market dynamics, price and profitability plus delivered cost competitiveness were reviewed for a new potential methanol investment. Special attention was paid to likely future alternative price-setting mechanisms if all price-influencing capacity in North American and Europe were to close
- **Market Study** - Independent market consultant to WestLB as Joint Lead Arranger for a proposed methanol plant in Western Australia reviewing the supply/demand and pricing prospects for methanol, the delivered cost competitiveness of the plant and the marketing strategy for the product

- **Methanol Market Consultant** - A review of global markets, pricing and delivered cost competitiveness for a Saudi Arabian company wishing to invest in a methanol project in the Kingdom
- **Methanol Existing and New Potential Markets for an African Project** - Nexant reviewed methanol and DME market dynamics, with a special focus on African and Indian opportunities, and developed pricing projections and a market entry strategy. New and emerging methanol markets included DME, gasoline blending, gasoline/synfuels, propylene, biodiesel, power, fuel cells. A value chain analysis (including cost of production and cost to market estimates) for each was performed to identify segments which were most attractive to an African location
- **Liquid Phase Methanol Plant** - The design of a two-stage liquid phase large-scale methanol plant for EPRI. Liquid phase methanol process development unit: installation, operation and support studies for the United States Department of Energy and Air Products and Chemicals
- **The Development of the Global Methanol Industry** - A report chronicling the historical development of the global methanol industry for the United States Department of Energy
- **Floating Methanol Plant** - Evaluation of the feasibility of a floating methanol plant in south-eastern Asia for a project sponsor
- **Point Lisa's Methanol Project Assistance** - A series of studies including evaluation of the project, assessment of the global markets for methanol and the evaluation of engineering contractor submissions for a 1 200 tons per day methanol plant for the National Energy Corp of Trinidad and Tobago Limited
- **Production of Methanol from Oil Residue in Germany** - In this study for a major global methanol producer, the alternative value of heavy fuel oil to German refineries was determined and the cash cost of production of methanol was calculated for each of the three German methanol producers using this feedstock, taking due account of the integration with the refinery and with associated hydrogen and ammonia plants
- **Large-Scale Methanol Pre-Feasibility** - A pre-feasibility study including pricing prospects and cash flow analysis for a prospective large-scale methanol plant in Nigeria
- **QAFAC Methanol/MTBE Market Due Diligence** - A study carried out on behalf of the banks arranging the loan facility for the Qatari methanol/MTBE project. The study included global and regional supply/demand analyses and forecasts, price forecasts, an analysis of the project's potential competitiveness in its key markets and a review of feedstock and off-take agreements
- **Global Methanol Business Outlook** - A study considering the likely change in U.S. demand for MTBE and potential growth of fuel cell usage. The study included global and regional supply/demand outlook, price forecasts and an analysis of the competitiveness of the Middle Eastern client's proposed plant against international competition
- **"New Paradigm" Methanol Pricing Outlook** - Changing market dynamics in the methanol industry have caused many plants to close in North America. Once the final U.S. gas-based plant closes, the historically strong influence of U.S. gas costs on global methanol prices will cease and a "new paradigm" price-setting mechanism will emerge. This study projected future methanol prices under this new paradigm with some sensitivity cases also considered
- **Strategic Planning** - Nexant was engaged by a Middle East methanol producer to identify opportunities and develop a strategy for further profitable growth
- **Technical and Market Advice for New Methanol Project** - Technical and market consultancy services to Société Générale making assessments and recommendations from the standpoint of potential lenders to a proposed methanol plant in Western Australia including technology selection, project development, review of gas supply, EPC, O&M and offtake contracts and a market study

reviewing of the supply/demand and pricing prospects for methanol, the delivered cost competitiveness of the plant and the marketing strategy for the product

6.4 COAL TO CHEMICALS

- **Coal to Chemicals: Is it Coal's Time Again?** - Coal may be ready to once again attain a key role in the global chemical industry. In this multiclient report Nexant examined cost of production for the production of chemicals using both coal and conventional feedstocks in China and the United States. The report includes chemicals from synthesis gas technologies: methanol, ammonia, methanol to olefins, acetic acid, and formaldehyde. Chemicals from acetylene technologies: acetylene, BDO via acetylene/formaldehyde (REPPE concept), VCM, vinyl acetate, acrylic acid via REPPE process. Chemicals from emerging technologies: direct ethylene oxidation
- **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 Coal to Olefins Business Analysis. Confidential – Nexant prepared a detailed market analysis for a major chemical producer in Thailand
- **Chemicals from Acetylene: Back to the Future?**
- **Coal to Chemicals Project Due Diligence. Confidential** - Nexant prepared a market assessment, pricing forecast, technology assessment, financial assessment, and strategic analysis covering methanol and dimethyl ether (DME)
- **Coal to Olefins** – This report, part of Process Evaluation/Research Planning (PERP) Program, discusses the technology, market analysis and economics behind coal to olefins. Some of the technologies covered include: BGL process, HT Winkler fluidized bed gasifier, SFG gasifier, Lurgi dry-ash gasifier, U-GAS fluidized-bed gasifier, Lurgi MEGA methanol process, Lurgi MTP process, UOP/Hydrop PTO process, and DMTO process
- **Feasibility Study for Shenyang Polygeneration Project** - Nexant preformed a feasibility study to confirm the economics of the Hunnan International Technopolis Shenyang (HITS) polygeneration plant based on the specific coals available in the region and market values of plant products, methanol and dimethyl ether (DME). This project was funded by U.S. Trade & Development Agency (USTDA) and co-authored by China Petroleum and Chemical Industry Association (CPCIA) for Dalian Shide Group Co., Ltd. The feasibility study covered: polygeneration, cogeneration facility, and coal, coal to chemicals, coal gasification, and methanol to olefins (MTO)
- **Polygeneration from Coal: Integrated Power, Fuels and Chemicals** – This multiclient report was issued as two reports. The first report analyzes the technologies and economics of utilizing coal in an integrated facility to produce both electric power and major petrochemicals or liquid fuels using high-efficiency coal gasification and integrated downstream processes. The second report examines the viability of polygeneration from coal technology by reviewing and assessing both the technologies and costs for the power plus chemicals or liquid fuels processes versus the costs for the chemicals or liquid fuels from conventional commercial processes and feedstocks
- **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

- **Coal to Methanol Market Assessment** - The objective of this study is to perform an assessment of methanol markets, both traditional and emerging, and to provide non-proprietary inputs for an existing methanol market assessment study
- **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
- **MTO Commercial and Technical Risk Assessment** - Nexant was retained by the sponsor and its financial advisor to review market dynamics and pricing outlooks, perform risk assessments for the air separation unit (ASU), methanol, methanol to olefins (MTO) with olefin cracking process (OCP) and polyolefin process technologies, critical equipment risk assessment for the methanol, MTO-OCP and ASU plants and also a high-level social and environmental awareness overview.

6.5 SPECIFIC EXPERIENCE IN OLEFINS AND POLYOLEFINS

Nexant has completed numerous technical and commercial engagements focusing on the olefins industry as well as on polyolefins technologies and businesses.

Nexant offers its **PolyOlefins Planning Services (POPS)**, an annual subscriber service providing global information on current commercial, technical and economic developments in the LLDPE, LDPE, HDPE and Polypropylene industries. Coverage includes: supply/demand, swing potential, trade, operating rates, price forecasts, technological developments, new products, intermaterial substitution and regional competitiveness. This program provides Nexant a means to have continual update of industry developments and a means to interact with industry participants (for information development requirements), on an anonymous basis, as needed.

A partial list of projects relevant to olefins and polyolefins includes:

- **Petrochemical Market Dynamics: Feedstocks** – This multi-client report provides an analysis of the feedstock requirements for basic chemical production, and addresses which feedstocks will be important to the industry going forward. This report highlights emerging feedstocks, such as shale gas, as well as conventional materials including coal
- **North American Polyethylene Cost Structure** - This multi-client report provides an analysis of production costs by region, accompanied by an in-depth discussion on natural gas availability in North America and ethane availability and pricing. The impact of increased shale gas and associated NGL production on the North American feedstock slate used for olefins production is analyzed
- **Ethylene** - This PERP report discusses commercial and near commercial technology for producing ethylene, developing technologies, cost of production estimates for the manufacture of this olefin, and analysis of the commercial market. Cost issues associated with various feedstocks such as ethane, E/P, propane, n-butane, isobutane, light naphtha, and gas oil are analyzed
- **Gas to Ethylene** – This PERP report highlights new and emerging natural gas-based routes to ethylene which are compared to conventional ethane-based steam cracking. Also, the cost of production for ethylene is analyzed for feedstock and by-product pricing sensitivity, economy of scale sensitivity, and capital investment sensitivity
- **Feedstocks Sourcing and Competitiveness** - This multi-client report provides an overview of the global and regional ethylene and propylene markets and examines and compares the process technologies and economics of the commercially available and developing technologies for the

production of ethylene/propylene. The report also includes an analysis of regional competitiveness of both conventional and developing ethylene and propylene technologies

- **Methane to Polyolefins Feasibility Study** - Nexant was retained to develop an independent feasibility study for this project, including detailed market and price analyses and forecasts; market strategy and off-take agreement development; gas feedstock analysis and agreement formulation; technology analysis and selection (for methanol, olefins via MTO or MTP, and polyolefins); configuration and product optimization; capital and operating cost estimation and forecasts; detailed economic and cash flow evaluation; and investment recommendations
- **Adding Value to Methane: Strategic Opportunities for the Middle East** - This major study reviews (by each Middle Eastern State) methane availability and pricing issues, methane derivative market dynamics and impact on global trade, technology options, impact of these developments on competitiveness, extending the methane value chain and other strategic issues. The methanol chain products included are methanol, formaldehyde, acetic acid, DME, MTO and MTP. Also included are ammonia and its derivatives, GTL, LNG, pipelines and power
- **MTO Commercial and Technical Risk Assessment** - Nexant was retained by the sponsor and its financial advisor to review market dynamics and pricing outlooks, perform risk assessments for the air separation unit (ASU), methanol, methanol to olefins (MTO) with olefin cracking process (OCP) and polyolefin process technologies, critical equipment risk assessment for the methanol, MTO-OCP and ASU plants and also a high-level social and environmental awareness overview
- **Evaluation of Gas Monetization Options** - Nexant analyzed markets, pricing, capital and operating costs, delivered cost competitiveness and financials (including sensitivities) for nine gas monetization options including methanol, methanol to DME, methanol to olefins (with and without olefin conversion) and methanol to propylene. A SWOT analysis was performed and the options were ranked by various financial measures

6.6 PROPYLENE

6.6.1 Selected Special Industry Reports

Nexant's comprehensive topically selected reports alert industry personnel to emerging trends and factors with significant potential to affect selected business sectors. Besides presenting important data on occurrences and impacts, these publications deliver penetrating technoeconomic, commercial and strategic analyses. Recent industry reports include:

- **Evolving Propylene Sources: Solution to Supply Shortages** – Propylene was historically available as a co-product of naphtha cracking. The switch to lighter feedstocks from shale gas results in a decline in cracker propylene co-production. This multi-client study examines and compares the process technologies and economics of conventional as well as newer commercial propylene technologies that may alleviate the shortage. The report also explores the causes and effects of the propylene shortage in North America, including ways the North American propylene and derivatives industry has responded to changes in propylene supplies and higher propylene prices
- **Technology Developments in Propylene and Propylene Derivatives** - This multi-client report examines and compares the process technologies and economics of the commercially available and developing technologies for the production of propylene alone or as a co-product. The report focuses on the economics of alternate routes to propylene, how they compare to conventional routes, and how competitive they are. Conventional propylene technologies, such as, conventional steam cracking, production and recovery from refinery streams, and propane dehydrogenation, are compared to the new and developing technologies for propylene production. Newer developments in alternate technology and feedstock sources, and those technologies designed to either produce propylene exclusively or increase propylene yields from conventional sources, such as olefin

metathesis, catalytic pyrolysis, natural gas based processes, methanol-to-olefins, and methanol-to-propylene are examined and analyzed

- **New Technology Valuations: The Values of Technologies Under Development** - This study evaluates the intangible assets represented by chemical and energy process technologies that are in the research and development (R&D) phase. These technologies are not yet commercialized but appear to have significant economic value. The study surveys twenty promising technologies and explains Nexant's assessment of their value. The technologies reviewed in the study included: propylene via MTP (such as Lurgi's); propylene (poly grade) via metathesis; propylene oxide (PO) via HPPO (such as BASF-DOW), and acrylonitrile (ACN) via propane ammoxidation with oxygen (recycle)
- **Technology Developments in the Polyolefins Industry** - The polyolefin industry has entered a competitive era caused mainly by the proliferation of readily available production technology, low market entry barriers, and the resulting oversupply. To retain a competitive edge, manufacturers need to keep abreast of technological developments. These developments include: metallocene/single-site catalysts; functionalized propylene; branched LLDPE; syndiotactic polypropylene; gas phase-based high alpha-olefin LLDPE (C 8+); cyclic olefin copolymers; nonpelletized polyethylene and polypropylene; in situ comonomer generation in LLDPE processes; CATALLOY and related product technology; gas-phase bimodal HMW HDPE; dual catalysts for single-reactor bimodal HMW HDPE. This study reviews and analyzes technological advances in polyolefin production, providing a perspective of the significance of these evolutionary and revolutionary developments and evaluates their likely impact on the polyolefin industry
- **Alternative Routes To Propylene** - This Process Evaluation/Research Planning (PERP) report discusses the technology, market analysis and economics of on-purpose propylene. Some of the technologies covered include: steam cracking of ethane followed by dimerization and metathesis; biodiesel glycerine via hydrogenation to n-propanol followed by dehydration; raffinate-1 via isomerization and metathesis of butenes; oxidative dehydrogenation (ODH)
- **'Green' Propylene** - This PERP report discusses several routes to producing propylene from renewable feed. Several cases are considered herein for the production of green (or sustainable) propylene: Case 1: Fermentation of sugars to produce bio-ethanol is followed by dehydration to bio-ethylene. A portion of the ethylene is dimerized to produce normal butenes. The bio-butenes are then reacted with the remaining bio-ethylene via metathesis to produce green propylene. Butene-1 is isomerized to butene-2 (both cis and trans isomers) in the latter reaction. Case 2: Butanol is produced either by fermentation of sugars (Case 2a) or gasification of biomass (Case 2b) and the bio-butanol is dehydrated to produce bio-butene. The bio-butene is reacted with bio-ethylene as above. Case 3: Bio-propane produced as a by-product of biodiesel is dehydrogenated to produce green propylene. Case 4: Vegetable oil is fed to an enhanced fluid catalytic cracker (FCC) unit to produce green propylene. Case 5: Gasification of biomass to produce a syngas is followed by synthesis of bio-methanol. Green propylene is then produced via methanol-to-olefins technology
- **Propylene** - This recent PERP report discusses the chemistry, process technology, and production economics for propylene manufacture. Special emphasis is given to the on-purpose routes: metathesis, selective olefin cracking, MTO/MTP, propane dehydro and enhanced FCC. Regional supply/demand/trade forecasts are also provided
- **Propylene Technology: The Next Generation** - This multi-client study provides an in-depth quantitative and qualitative analysis of various new and developing technologies for the production of propylene via conventional and emerging process routes and conventional and non-conventional feedstocks, including biomass. The report examines conventional propylene technologies: steam cracking, refineries, propane dehydrogenation (PDH), olefin metathesis, catalytic cracking. Developing technologies include: biopropylene (NExBTL–Neste Oil) and enhanced FCC

(PetroFCC- UOP). The study also discusses alternate feedstocks, including natural gas and coal, propylene economics (by-product propylene and on-purpose propylene), regional competitiveness, and sensitivity analysis

- **Petrochemical Market Dynamics: Propylene and Derivatives** - This report is part of the Petroleum & Petrochemicals Economics (PPE) program which has provided accurate data, insightful analysis and dependable forecasts of the profitability, competitive position and supply/demand trends of the global petroleum and petrochemical industry. The market dynamics report analyzes the market dynamics for propylene derivatives, including polypropylene, acrylonitrile, propylene oxide, acrylic acid, phenol and cumene

Other related special industry reports include:

- An In-Depth Analysis of the Polypropylene and Polyethylene Industry in China
- Strategic Assessment of Middle East Impact on the Asian Petrochemical Industry
- Chemicals and Plastics in China
- Latin American Energy, Refining and Petrochemical Industries in Transition
- The Global Polyolefin Industry: Recovery in a Period of Structural and Technological Change

6.6.2 Selected Project Experience in Propylene

- **PDH Project Pre-Feasibility Study** – Nexant was retained to evaluate the feasibility of a project to produce propylene and derivatives based on propane dehydrogenation (PDH) process for a client in the Middle East. The pre-feasibility study and screening analysis covered propane dehydrogenation (PDH), propylene and propylene derivatives
- **PDH/Polypropylene Independent Technical Consultant Review. Confidential** – Nexant was engaged as an independent technical consultant for a propane dehydrogenation and polypropylene project including monitoring
- **Propane Dehydrogenation/Polypropylene Pre-Feasibility Study** - For a major Korean petrochemical company, Nexant prepared a pre-feasibility study on propane dehydrogenation and polypropylene
- **Propane Dehydrogenation and Polypropylene Pre-Feasibility Study. Confidential** – This pre-feasibility study on propane dehydrogenation and polypropylene provided a market analysis on polypropylene, reviewed PDH technology and licensors, and cost competitiveness, and provided cost of production estimates. The regional focus of the study was Algeria and Africa
- **PDH/Polypropylene Independent Technical Consultant Review. Confidential** - Nexant was engaged as an Independent Technical Consultant to assist in the due diligence for a planned expansion project of a polypropylene production facility in Thailand
- **PDH/PP Independent Environmental Consultant Review. Confidential – Nexant was retained as** Lenders environmental consultant for HMC PDH and polypropylene production project in Thailand
- **Propane Dehydrogenation Review** - Nexant was retained to prepare an independent review of the STAR process on behalf of prospective licensees and lenders to a project employing Uhde's STAR propane dehydrogenation technology
- **Propylene, Ammonia, and Acrylonitrile Study. Confidential** - Evaluation of potential investment in a U.S. acrylonitrile manufacturer. Nexant provided an assessment of the market outlook, profitability, and operating cost benchmarking. Forecasts pricing of crude oil, propylene, ammonia and acrylonitrile
- **North American Propylene Chain Competitiveness Analysis** - Summarizes key aspects of the North American propylene-polypropylene fabricated products value chain. It takes account of a

globalized world and future investments in the world and in this region, in particular in Venezuela and Trinidad and Tobago. The study includes: Propylene availability in the NAFTA region: refinery propylene availability, steam cracker, on purpose technologies, propylene supply, demand and trade. Cost analysis: cost of production, cash costs and cost curves. End product trade and competitiveness: end product global trade impact on the NAFTA region; end product manufacturers competitiveness; end product market dynamics and net trade outlook; polypropylene trade (Latin America, Europe, Asia Pacific, loss of propylene in imported products, U.S. propylene price setting status and impact of Venezuela and Trinidad)

- **Fermentation Propanol to Green Propylene. Confidential** - This report identifies discusses four routes to producing propylene from renewable feedstock (corn, sugarcane and glycerine). The study included cost of production estimate for selected process technologies, including: corn ethanol dehydration to ethylene, propylene via metathesis, sugarcane ethanol, sugarcane ethanol dehydration to ethylene, ethylene (sugarcane based) dimerization to butenes, and propylene via metathesis
- **European Propylene Supply. Confidential** – Discusses the propylene and propane markets, pricing and cost competitiveness
- **Propylene Derivatives Options Study** - National Polypropylene Company (NPPC) together with Vinmar, in a joint venture known as the PUPS project, is currently investigating options to add value to propane through dehydrogenation to propylene. NPPC already has a polypropylene project under development and is keen to diversify into other propylene derivatives based on an additional propane dehydrogenation facility. It is also considering an additional PDH complex (the PUPS project). Considering Saudi Aramco's intentions not to promote further polypropylene based on PDH in the Kingdom, PUPS is keen to evaluate other propylene derivatives configurations for this proposed PDH complex. The objective of the engagement is to provide relevant market, technology and profitability insights into the potential products based on propylene produced from a PDH plant. Key findings and recommendations for optimum downstream derivative complex configurations have also been included as a point of departure for future detailed analyses
- **Feasibility for Investment in Polypropylene** – For a Middle East client with an opportunity to invest in polypropylene and propane dehydrogenation technology, Nexant was retained as the Lenders' market consultant for financial approval through to close of the project. Nexant reviewed the options available for a potential new investor to develop a polypropylene business based on refinery propylene. The study covered the competitive structure based upon the potential for local feedstock sources and technology considerations
- **Propane-propylene based industries in Saudi Arabia** - To assess the feasibility of establishing an integrated industrial complex based on the production of propylene by the propane dehydrogenation process
- **Polypropylene Markets/Margins** - For a U.S. producer, Nexant provided a near-term outlook on propylene and polypropylene that included: supply/demand globally and for ASEAN, and prices/margins including relationship between U.S. Gulf Coast and Asia
- **Propylene and polypropylene. Confidential** – Nexant assisted a U.S. petroleum company in evaluating investment opportunities in a joint venture to produce propylene and polypropylene at a Louisiana refinery. Nexant prepared a spreadsheet model of the plant to forecast costs, revenues and evaluate future cash flow. The study was conducted in a series of reports to include an evaluation of propylene and polypropylene at the refinery, competitive assessment, opportunities for propylene and its derivatives, and commercial analysis
- **Petrochemical Industry Development** - Nexant performed extensive work on the development of an olefins-based petrochemical industry in the Philippines; and was retained jointly by an international oil company and a domestic Philippine company to act as consultant in the planning

of a large olefins-based chemical and petrochemical project. Feedstocks were from an existing domestic petroleum refinery and products were primarily for the domestic markets, with export markets considered in developing plants of adequate economic scale of production. The process plants involved in these studies were chlorine, caustic soda, ethylene, and propylene, HDPE, LDPE, PVC and VCM. Nexant's supplied raw material supply and price assessments and analyzed the interaction of the petrochemical complex with the adjacent refinery. The study also included: product pricing and markets (both domestic and export factors); cost of production (COP) estimates that established the plant size needed to be competitive with future world-scale plants; discussions with potential joint venture partners, analyses of project financing plans, reviews of managing contractors, and establishment of project definition documents. The second phase of work involved Nexant efforts on behalf of the Philippine National Oil Company (PNOC), to encourage and develop the project. This work involved: further analysis and recommendations on plants to be included; evaluations of government strategy, national benefits, public sector participation, and the policies and support that are necessary and appropriate to develop this project. Nexant had a resident consultant in Manila working as part of the petrochemical task force

- **Strategic Opportunities** - Nexant suggested that this client could add value and increase profits in its refining business by upgrading streams and producing higher value products. Nexant identified suitable projects; such as recovering propylene or aromatics and manufacturing cumene or other derivative, recovering ethylene or upgrading saturated C4 streams; and suggested various approaches that would contribute to the success of this strategy
- **Polypropylene Due Diligence** - A Japanese bank considering the revision of financing for an Indonesian polypropylene project engaged Nexant as advisors who understood the interaction between olefin operations, petroleum refineries, polypropylene technologies and markets and the relationship of polypropylene to other polymers. Nexant provided: a market forecast for propylene and polypropylene with an outlook for Indonesia and Southeast Asia; price forecasts for propylene and polypropylene in Asia; and a review of operations, costs and price/margin projections of the financed plant
- **Petrochemical Market and Technology Review – Confidential.** Nexant was retained to perform a techno-economic evaluation for selected petrochemical products, covering the supply, demand and pricing in Russia, including export pricing, together with details of the production processes and an HSE review of waste streams. The selected products included: alpha olefins, ethylene oxide/ethylene glycol, propylene oxide/propylene glycol, polypropylene, polystyrene, ethyl benzene, styrene monomer, MMPA and PMMA
- **Petrochemical Project Pre-Feasibility Study – Confidential.** An in-depth market analysis and technical review on the ethylene, propylene, nylon and acetic acid derivatives for a petrochemical project in Saudi Arabia
- **C₃ Market Study** - In support of a C₃ splitter project an international client was developing with a Venezuelan refiner, Nexant conducted a propylene and propane market study. The objective of the assignment was to identify target markets over 1996-2013 for Venezuelan exports of polymer grade propylene and propane and determine which would offer the best netback price. Tasks included development of: global supply/demand balances by region for both products for the selected time period; more detailed demand forecasts according to end uses; global trading patterns; regional factors driving supply and demand; and price forecasts. Based on the projected balances and prices, Nexant calculated Venezuelan netback values for identified target markets which, when combined with transportation and terminaling costs, resulted in a ranking
- **Feasibility for Investment in Polypropylene** - This report was undertaken for a Middle East client with an opportunity to invest in polypropylene and propane dehydrogenation technology. Subsequently work was undertaken as the Lenders' Market Consultant for financial approval through to close of the project. In addition the options available for a potential new investor to

develop a polypropylene business based on refinery propylene were reviewed. In this case the study covered the competitive structure based upon the potential for local feedstock sources and technology considerations

- **Propylene and Polypropylene Investment Opportunity – Confidential.** Nexant assisted in evaluating investment opportunities in a joint venture to produce propylene and polypropylene refinery in the United States. Nexant provided a financial model of the plant to forecast costs, revenues and evaluate future cash flow. The study provided a series of reports that included an evaluation of several propylene and polypropylene plants, opportunities for propylene and its derivatives, commercial analysis, supply/demand and trade, profitability and market share
- **Olefins and Derivatives Market Evaluation -** A Thai olefins producer requested an updated market and price outlook for olefins, derivatives and feedstocks. Nexant provided historical and forecast supply/demand/net trade outlooks for major petrochemicals. Naphtha through ethylene and propylene to the polyolefins and other derivatives were included. Price forecasts were prepared using the low-oil and base-oil scenarios
- **Olefins and Aromatics Business Analysis -** As part of the in-house review of strategic options with a major U.S. petrochemical producer, Nexant was called upon to provide background information on olefins and aromatics and a financial model for the client's use. The specific information included: technology barriers that would keep the client from participating in any of the value chain for the following: ethylene, propylene, benzene and xylene and all derivatives; For selected countries throughout the world, Nexant also provided: an outlook for supply/demand, including trade of derivatives; supply demand outlook for naphtha feedstock; driving forces impacting profitability; political/governmental factors (taxes, incentives, tariffs) that affect profitability; opportunities for petrochemicals with emphasis on refinery integration and the options open to the client
- **Olefins and Derivatives Markets -** This study was prepared for a company considering the construction of a new steam cracker that would use ethane, LPGs, and/or other feedstocks. Nexant was asked to provide data, analysis and opinions on the economics of alternative feedstocks and the future global markets for ethylene, propylene, and major derivatives. Potential target markets were also identified. As part of the analysis, Nexant evaluated several potential crude scenarios and the impact each scenario would have on feedstock (e.g. naphtha, ethane, butane, etc.) costs and subsequent olefins manufacturing costs. Pricing mechanisms and forecasts were developed for ethylene and propylene, as were global supply/demand forecasts for all major derivatives
- **Olefins Pricing -** An analysis of the basis for pricing of deep sea ethylene and propylene with recommendations for a purchaser's future contract policy. The study established bases for pricing in all major regions and, using netback analysis, identified most likely future supply patterns

6.7 POLYPROPYLENE

- **Feasibility for Investment in Polypropylene** – For a Middle East client with an opportunity to invest in polypropylene and propane dehydrogenation technology, Nexant was retained as the Lenders' market consultant for financial approval through to close of the project. Nexant reviewed the options available for a potential new investor to develop a polypropylene business based on refinery propylene. The study covered the competitive structure based upon the potential for local feedstock sources and technology considerations
- **Polypropylene Due Diligence** - A Japanese bank considering the revision of financing for an Indonesian polypropylene project engaged Nexant as advisors who understood the interaction between olefin operations, petroleum refineries, polypropylene technologies and markets and the relationship of polypropylene to other polymers. Nexant provided: a market forecast for propylene and polypropylene with an outlook for Indonesia and Southeast Asia; price forecasts for propylene and polypropylene in Asia; and a review of operations, costs and price/margin projections of the financed plant
- **Olefins and Derivatives Markets** - This study was prepared for a company considering the construction of a new steam cracker that would use ethane, LPGs, and/or other feedstocks. Nexant was asked to provide data, analysis and opinions on the economics of alternative feedstocks and the future global markets for ethylene, propylene, and major derivatives. Potential target markets were also identified. As part of the analysis, Nexant evaluated several potential crude scenarios and the impact each scenario would have on feedstock (e.g. naphtha, ethane, butane, etc.) costs and subsequent olefins manufacturing costs. Pricing mechanisms and forecasts were developed for ethylene and propylene, as were global supply/demand forecasts for all major derivatives
- **Market Study** - In support of a C3 splitter project an international client was developing with a Venezuelan refiner, Nexant conducted a propylene and propane market study. The objective of the assignment was to identify target markets over 1996-2013 for Venezuelan exports of polymer grade propylene and propane and determine which would offer the best netback price. Tasks included development of: global supply/demand balances by region for both products for the selected time period; more detailed demand forecasts according to end uses; global trading patterns; regional factors driving supply and demand; and price forecasts. Based on the projected balances and prices, Nexant calculated Venezuelan netback values for identified target markets which, when combined with transportation and terminalling costs, resulted in a ranking
- **Market Evaluation** - A Thai olefins producer requested an updated market and price outlook for olefins, derivatives and feedstocks. Nexant provided historical and forecast supply/demand/net trade outlooks for major petrochemicals. Naphtha through ethylene and propylene to the polyolefins and other derivatives were included. Price forecasts were prepared using the low-oil and base-oil scenarios
- **Business Analysis** - As part of the in-house review of strategic options with a major U.S. petrochemical producer, Nexant was called upon to provide background information on olefins and aromatics and a financial model for the client's use. The specific information included: technology barriers that would keep the client from participating in any of the value chain for the following: ethylene, propylene, benzene and xylene and all derivatives; For selected countries throughout the world, Nexant also provided: an outlook for supply/demand, including trade of derivatives; supply demand outlook for naphtha feedstock; driving forces impacting profitability; political/governmental factors (taxes, incentives, tariffs) that affect profitability; opportunities for petrochemicals with emphasis on refinery integration and the options open to the client
- **Polypropylene Opportunity Evaluation** - Nexant updated the findings of an earlier evaluation on the potential for the propylene recovery followed by conversion into polypropylene to include additional products, potential customer sales and strategic alliances. In addition, Nexant analyzed

the potential for a new ethylene plant in the USGC adjacent to an existing refinery. The plant profile consisted of: plant size, feedstocks and products; land and investment requirements; technology and project economics; supply/demand; and potential partners

- **Polypropylene Business Analysis** - For a company considering a plan to recover propylene from its refinery and upgrade its value by producing polypropylene as a new business venture, Nexant provided a technical and commercial evaluation that included a competitive analysis with each producer's cost structure by site, their market position, and propylene position. Industry structural issues, including transportation logistics, geographic sales distribution, operating rates and their impact on pricing, were also considered. Nexant also reviewed the client's financial model that covered commercial and economic inputs such as licensing fees, production costs, pricing, and volume
- **Polypropylene Market Report** - For a European polypropylene producer, Nexant provided global and Western European propylene and polypropylene market overviews. The study included projections of ethylene, propylene and polypropylene profitability to 2020 for Western Europe
- **Polymer Market Analysis – Confidential.** The objectives of this analysis are to prepare independent market outlooks for a selected number of products of interest to the client; to assess the competitiveness of their LDPE, HDPE and polypropylene units in relation to selected competitors and benchmarks; and to develop West European price forecasts for a number of materials (plus an estimate of any additional premiums or discounts the client enjoy in the Romanian and Turkish markets for these products). The products covered are: polypropylene, HDPE, LDPE, LLDPE, PVC, PET, polypropylene copolymers (impact/block, and random) and polypropylene compounds. Primary countries covered by the study are Romania and Turkey, plus secondary markets, the Former Yugoslavia, Russia, Ukraine and Bulgaria. The report also includes West European price forecasts for the products listed above, plus ethylene and propylene (polymer and chemical grade)
- **Petrochemical Product Screening** - Market study of a vast variety of petrochemicals that could potentially be produced at PDVSA's Amuay and Cardon refineries in Paraguay. Products included are ethylene, HDPE, propylene, polypropylene, polystyrene, benzene, cumene, and many others

6.7.1 Selected Project Experience in Impact Polypropylene Copolymers

- **Polyolefins market study.** Nexant contributed a market analysis to a Conceptual Engineering Study for a new olefins and polyolefins complex in Bolivia. Nexant assessed supply, demand and pricing trends for polypropylene (including impact copolymers), LDPE, LLDPE, and HDPE markets in Bolivia, Argentina, Brazil, Chile, Ecuador, Paraguay, Peru, and Uruguay and the main markets in Europe, the United States, and Asia. (Tecnimont SpA, a member of the Maire Tecnimont Group; 2013)
- **Market Analysis – Confidential.** The objectives of this analysis are: to prepare independent market outlooks for a selected number of products of interest to the client; to assess the competitiveness of their LDPE, HDPE and polypropylene units in relation to selected competitors and benchmarks; and to develop West European price forecasts for a selected products. Products covered included: polypropylene, HDPE, LDPE, LLDPE, PVC, PET, polypropylene copolymers (impact/block, and random) and polypropylene compounds. Primary countries covered by the study are Romania and Turkey, the Former Yugoslavia, Russia, Ukraine and Bulgaria

- **U.S. Polypropylene Impact Copolymer Market** - Nexant supported the planning efforts of a company competing in polypropylene impact copolymers by providing a detailed market analysis including end-use market segmentation and pricing: batteries; automotive; housewares; outside furniture; medical packaging and toys etc. Nexant developed extended forecasts by application and identified the major segment suppliers. Fabricators, competitive products, materials substitution and market forces were also discussed
- **Polypropylene Compounding** – This issue of the multiclient Process Evaluation/Research Planning report series describes the technology for manufacturing polypropylene compounds. In addition, it provides a cost of production analysis and a ten-year supply/demand forecast. (PERP, Dec 2005)
- **Polypropylene Technoeconomic Evaluations** - A Japanese company, in announcing the development of a polypropylene process for the manufacture of homopolymer, random and impact copolymer, was interested in understanding various state-of-the-art polypropylene technologies. Nexant carried out a detailed technology and economic assessment of leading polypropylene technology. The licensing experience and product capabilities were detailed
- **Polypropylene Market Study – Confidential.** The Brazilian subsidiary of an international chemical producer considering the construction of a polypropylene plant in Brazil required detailed information on the Brazilian/Mercosul polypropylene market as a preliminary to securing financing and maximizing production and profitability. Nexant supplied a country overview (economic growth, demographics, trade, consumption), market analysis by application for the homopolymer, random and impact copolymer (process exports, intermaterial/interpolymer competition, resin selection criteria, emerging applications, compounding), market structure (customer analysis and regional distribution), outlook covering capacity, supply, demand, trade and operating rates, opportunity analysis and strategy recommendations
- **Polypropylene Compounds** – This supplement to the multiclient Polyolefins Planning Service series characterizes four categories of compound. It describes the structure of the industry, the compounding process (including equipment) and the economics. It analyzes trends and provides a region-by-region commercial analysis. (POPS, Nov 2005)
- **Polypropylene Acquisition Study** – Nexant provided an industry overview and business position analysis of the polypropylene industry covering supply/demand, producer analysis and profiles, copolymer analysis by producer, and cost of production
- **Polypropylene Technology and Product Analysis** - In order to assist Himont with its licensing Nexant was asked to prepare an impartial report comparing the Himont and Unipol/Shell polypropylene processes. The comparison is done for two aspects: technology costs (capital and operating), product capability and acceptability. The results of the study are based on extensive field contacts with licensees, producers, licensors, and end-use customers and fabricators in the United States, Western Europe and Korea. Applications covered included: copolymer application, random copolymers, automotive bumper covers, impact copolymer/low blush characteristics, heat seal resins, high rubber fraction copolymer for rubber replacement, and fiber application. Cost of productions estimates included polypropylene (Impact Copolymer Pellets) via Himont process, polypropylene (Impact Copolymer Pellets) via Unipol; process, and polypropylene (Sugar Impact Copolymer Pellets) via Himont process
- **Polypropylene** – The process technology and production economics for polypropylene (homopolymer and impact copolymer) are presented. This report is part of NexantThinking Process Evaluation/Research Planning (PERP) Program, a technology oriented program that analyzes the technological and commercial trends, and developments in areas of interest to the chemical and allied industries. PERP reports cover regional supply and demand balances, process economics, process design, markets and product applications, and regulatory issues

- **Polyolefin Planning Service (POPS)** – NexantThinking annual subscription program that provides reports on the global polyethylene and polypropylene industry, including impact copolymers. 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
- **Polypropylene Market and Technology Overview** – Nexant was retained to provide an overview of economics, producers, licensing, and markets for polypropylene and thermoplastic elastomers. The study included impact copolymer producers and technology, capital cost, licensing experience/restrictions, and producer product capability
- **Atactic Polypropylene in Western Europe** – Nexant was retained to provide market analysis and production economics for atactic polypropylene and the viability of constructing an on-purpose atactic polypropylene plant. The market analysis included high impact polypropylene copolymers, supply/demand, and demand by application/end product
- **Polypropylene Business Assessment** – For a major refining and marketing company in the United States, Nexant provided economics for polypropylene production using three scenarios: a base case, recession case and slow growth case. The study included pricing, cash margins, return on investment, existing versus new leader plants, operating costs, and cost of production for polypropylene, including random copolymer grade (bulk loop technology), low/medium impact grade (bulk loop technology), and high impact grade (bulk loop technology)
- **Polypropylene Copolymer Analysis** – Nexant was retained to analyze the impact copolymer business and provide an overview of polypropylene producers as to expansion plans and copolymer strategy. This analysis included economics, supply/demand and pricing for impact copolymer and random copolymer polypropylene, automotive plant list/capacity, Japanese automotive industry changes, supplier profile/capacity and export volumes. Costs of production estimates comparison were also presented for random polypropylene via Unipol, Himont and BASF process technologies, and for high impact polypropylene via Unipol process technology
- **Polypropylene Copolymers** - For a European producer, Nexant assessed competitor activity in special copolymers for use as heat sealing layers in biaxially oriented polypropylene and high impact polypropylene copolymers
- **Western European Polypropylene Pricing Study** – For an Italian chemical producer, Nexant developed a price comparison analysis for polypropylene, including random copolymer film, medium impact copolymer molding, high impact copolymer molding, and impact copolymer extrusion
- **United States Polypropylene Market** - For a Japanese chemical producer, Nexant was retained to assess the potential market expansion for block and random polypropylene copolymers especially for automotive and housewares usage of polypropylene
- **Polypropylene Technology and Manufacturer Analysis** – For a major chemical producer, Nexant prepared a technoeconomic analysis of the polypropylene producers in the United States and an economic evaluation of the different technologies employed for polypropylene manufacture, including polypropylene copolymers
- **Polypropylene Strategy Review** – Statoil retained Nexant to assess the strategy and economics of a joint venture with Himont to produce polypropylene including advanced polypropylene copolymers at Antwerp using propylene available from Stenungsund

7.1 CONTACT INFORMATION

AMERICAS

Nexant, Inc.
44 South Broadway, 4th Floor
White Plains, NY 10601-4425
U.S.A.
Attn: Randy Rabenhorst
Principal
Tel: + 1-914-609-0336
Fax: + 1-914-609-0399
Email: rrabenhorst@nexant.com

Or

Attn: Heidi Junker Coleman
Global Programs Support Manager
Tel: + 1-914-609-0381
Fax: + 1-914-609-0399
e-mail: hcoleman@nexant.com

EUROPE

Nexant Limited
1 King's Arms Yard, 1st Floor
London EC2R 7AF
United Kingdom
Attn: Anna Ibbotson
Principal
aibbotson@nexant.com

ASIA

Nexant (Asia) Ltd
22nd Floor, Rasa Tower 1
555 Phahonyothin Road
Kwaeng Chatuchak, Khet Chatuchak
Bangkok 10900
Thailand
Attn: Tiankanok Sirichayaporn
Senior Consultant
Tiankanoks@nexant.com

Nexant, Inc.

San Francisco
New York
Houston
Washington
London
Frankfurt
Bahrain
Singapore
Bangkok
Shanghai
Kuala Lumpur

www.nexant.com

www.nexantthinking.com

