Continuing Fortunes of the C₄ Value Chain

Prospectus

April 2020
SPECIAL REPORTS

Continuing Fortunes of the C4 Value Chain

Prospectus

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1 Continuing Fortunes of the C₄ Market

Nexant previously published a detailed analysis of the C₄ sector “The Developing Fortunes of the C₄ Value Chain”. At the time the C₄ market was transitioning through a period of structural changes that resulted in various market uncertainties and pricing spikes. The business landscape has evolved dramatically since the publication of Nexant’s first study in 2012. Today the C₄ value chain is exposed to an extraordinary set of circumstances that are shaping its prospects for development in the near term. These include:

- Global economic turmoil impacting demand due to the coronavirus pandemic.
- Declining refinery and petrochemicals production impacting feedstock availability.
- Structural changes in global olefin investments and feedstock selection.
- Uncertainties in natural rubber supply and pricing.

The future market outlook is dominated by a number of external uncertainties. These uncertainties, coupled with the complex nature of the C₄ value chain, present major challenges and opportunities for industry players covering the following:

- **Short-term** - declining demand for rubbers due to reductions in both automotive production and total miles driven in 2020. Sector margins are in decline, competitive rivalry is increasing along with prospects for industry restructuring and M&A.
- **Medium-term** - reduced availability of mixed C₄s remains a key issue for the supply side. Additional supply of mixed C₄s from ethylene production is in decline due to changes in technology selection and feedstock trends away from naphtha.
- **Longer-term** – implementation of new environmental initiatives will impact consumption trends for synthetic rubber markets. Technology innovation will continue to shape the automotive and tyre sector. New materials will be required to reduce emissions and energy consumption.

Taking into account these significant industry changes which have occurred since our last report, Nexant is developing a new report that provides detailed insights and analysis into the principal industry dynamics that will shape the C₄ value chain over the next decade. This new report will help our clients understand the issues and position themselves to effectively address the challenges that the industry faces.

This prospectus outlines Nexant's report scope along with details of key areas of focus, methodologies and previous sector experience.
1.1 C₄ Supply Drivers

1.1.1 Source of C₄ Supply

In general, petrochemical feedstock slates employed differ greatly by region due to availability and cost by location. This is more prevalent in the production of olefins where there are a number of different options available to producers in different geographies. Figure 1 displays global ethylene production by feedstock slate. Currently around half of the world’s ethylene capacity utilizes naphtha as its feedstock while ethane, other natural gas liquids, gas oil and methanol comprise the balance. Different steam cracker feedstocks provide contrasting yields of mixed C₄ streams. Generally, heavier feedstocks, such as naphtha and gas oils provide higher C₄ yields that make extraction and recovery both viable and increasingly attractive in terms of overall olefin production competitiveness.

Higher C₄ values have resulted directly from several key supply factors which include the following:

- A trend towards investments in lighter feedstock cracking, promoted primary by advantaged feedstock pricing and availability in the Middle East.
- Impact of shale gas in North America, leading to a shift towards lighter feedstock slates for olefin production.
- Other production trends for ethylene and propylene from non-conventional technologies such as coal-to-olefins, metathesis, propane dehydrogenation and biomass which do not yield mixed C₄ streams.
- Lower utilisation rates for selected higher cost naphtha steam cracker, resulting from decreased demand for ethylene and ethylene derivatives.

Figure 1 Indicative Estimate of Global Ethylene Feedstock Demand

Steam Cracker Products: Naphtha vs Ethane (Tons per ton of Ethylene)

Capacity to produce ethylene by feedstock type is an important component in determining the potential mixed C₄ availability. Nexant’s study incorporates detailed estimates of individual cracker production levels to determine the actual level of mixed C₄ available. Nexant’s database models each individual cracker in terms of capacity, production and feedstock slate to determine the overall C₄ balance in the market. The analysis in the study covers a 20-year timeframe to accurately present historic and forecasted trends of supply.

Figure 2 displays global ethylene capacity compared with the production and global mixed C₄ production. Nexant’s analysis further incorporates available C₄ versus production with estimates for butadiene production versus alternative processing and/or recycle co-cracking.
In the study, Nexant will provide detailed analysis of current C4 supply and forecasted trends on a regional basis. Nexant’s C4 availability is derived by a detailed analysis of individual steam cracker sites around the world. Key inputs include: capacity, production rate, C4 recovery and feedstock employed. This will provide a number of useful insights such as the impact of light gas cracker investments in the Middle East and the impact of shale gas on the sector in North America.

Figure 2 Illustration of Mixed C4 Potential Availability and Actual Production

1.1.2 Complexity of C4 Products Configuration

Figure 3 illustrates the many schemes for upgrading the C4 stream. The C4 flow scheme illustrates a wide variety of value added options for the C4 stream. Some options reflect very simple approaches to the C4 stream, (e.g., butadiene extraction and MTBE), whereas there are other options having additional complexity, including butene-1 extraction and other butylene derivatives. There is also considerable interaction with the refinery and the potential for blending refinery and petrochemical sourced C4 streams.

1.1.2.1 Selective and Full Hydrogenation

Hydrogenation processes for the mixed C4 stream are commercially available from Axens, UOP and Lummus. The product stream from full hydrogenation is a mixture of butanes and the product from selective hydrogenation is a so-called pseudo raffinate-1. The isobutylene content of this stream is about 20 to 22 percent (i.e., much less than in raffinate-1 from a butadiene extraction plant but higher than in a refinery sourced FCC C4 raffinate). This stream is suitable for isobutylene extraction and MTBE synthesis, but not certain grades of polyisobutylene, which require a minimum of 35 percent isobutylene in the feedstream. This stream has a value between that of a petrochemical raffinate-1 and raffinate-2. Raffinate-1 is normally processed further to MTBE while raffinate-2 is mainly used in polygasoline and alkylation or processed further to produce butene-1. In more recent years raffinate-2 has provided a key feedstock for metathesis processes to convert contained butene-2 and ethylene into propylene.

1.1.2.2 Butadiene Extraction

Quantities of C4 olefin by-products are generated during the manufacture of ethylene by the steam cracking of hydrocarbons, particularly when naphtha or heavier feeds are used. Butadiene is extracted from this mixed C4 stream using the principle of extractive distillation, since the relative volatilities of the various C4 isomers are such that they cannot be separated by conventional distillation.
Figure 3  Overview of C₄ Processing

Naphtha

Steam Cracker

Full Hydrogenation
Selective Hydrogenation
Butadiene Extraction

Butadiene sales

Raffinate-1 sales

Hydrogen
Fuel gas
Ethylene
Propylene
Pygas
Light fuel oil
Mixed C₄ sales

C₄ Chain

Recycle Co-Cracking

MTBE

Isobutane Dehydrogenation

Isobutylene sales
Isobutylene use
Raffinate-2 sales
LPG pool

Polyisobutylene
Iso-Octane
Butyl Rubber
Methyl Methacrylate
Polyisobutylene
Specialty Chemicals

SB Rubber
Polybutadiene Rubber
ABS Resins
SB Latex
Polyamide 66 intermediates
Thermoplastic plastomers

Skeletal Isomerisation

Butene-1 sales
Butene-1 use
LPG pool
Metathesis
Higher Oxsos

Raffinate-1

Hydroraffinate

Refinery (Mostly FCCCU)

Pseudo Raffinate

SB Rubber
Polybutadiene Rubber
ABS Resins
SB Latex
Polyamide 66 intermediates
Thermoplastic plastomers

Refrinery (Mostly FCCCU)

Isobutane Dehydrogenation

Isobutylene sales
Isobutylene use
Raffinate-2 sales
LPG pool

Polyisobutylene
Iso-Octane
Butyl Rubber
Methyl Methacrylate
Polyisobutylene
Specialty Chemicals

SB Rubber
Polybutadiene Rubber
ABS Resins
SB Latex
Polyamide 66 intermediates
Thermoplastic plastomers

Dimerisation

Butanes recycled to the steam cracker
1.2  \( \text{C}_4 \) Demand Drivers

The current market situation is highly uncertain due to the prevailing economic turmoil that exists today. Nexant will use its latest industry insights to create new up to date demand projections and incorporate and model different demand growth scenarios.

Nexant’s study will include a detailed assessment of major global markets for the \( \text{C}_4 \) stream and its purified components. This will include a full discussion of the industry structure and value chain in principal consuming regions.

The \( \text{C}_4 \) stream contains a number of valuable products that are used as feedstocks for a range of important derivatives. Applications include synthetic rubbers, engineering resins, fibre intermediates and fuel additives. Special focus will be given to the developments associated with the automotive and tyre industries.

**Figure 4  Butadiene Consumption by End-Use**

(2019)

The important questions to address include the following:

- What is the global economic outlook and its likely impact of \( \text{C}_4 \) derivatives demand?
- What are the key development trends in the automotive and tyre sectors?
- Will future \( \text{C}_4 \) supply and processing capacity meet future demand?

Nexant’s study will provide further insights into the natural rubber market along with longer-term pricing relationships with synthetic rubbers and discuss the impact and possibilities for material substitution in the tyre sector.
2 Report Scope

The objective of this report is to examine the current and forecast landscape of the C\textsubscript{4} sector chain. The study will provide a thorough understanding of the C\textsubscript{4} value chain and focus on the following key aspects of the sector:

- Current and developing economic trends and impact on the key end-use sectors.
- Evolving feedstock slate capacity developments for regional ethylene production and resulting C\textsubscript{4} availability and production.
- Refinery integration and C\textsubscript{4} supply potential for the chemicals sector.
- Alternative technologies to butadiene and production and relative competitiveness of non-conventional processes such as dehydrogenation and bio-based technologies.
- Highlight new environmental trends and potential impact on the automotive and tyre markets & technology.
- Sector market dynamics and pricing for butadiene, butylene, and major derivatives.
- Future price projections for key components such as butadiene, synthetic and natural rubbers.

2.1 Proposed Table of Contents

Nexant will provide a detailed market assessment on a quantitative and qualitative basis. The analysis will include data covering supply, demand, production and operating rates.

For the key products defined below Nexant will provide the following:

- A narrative summary of market characteristics, prospects and rationale, major trends and drivers for growth in end-use sectors.
- Outline key major issues that may impact consumption growth such as; economic downturn, material substitution, environmental or health and safety issues.
- A quantitative update of supply/demand and net trade by region and overviews of the global markets with regional breakdown.
- A summary of historic and forecast consumption, capacity, and operating rate, and implications for pricing.
- For each of the geographical regions, Nexant will carry out an analysis of the historical and forecasted total production capacity where known:
  - New capacity additions
  - Capacity rationalization
  - Operating rate assumptions

Nexant will provide a high level commentary for global and regional aspects of the market and describe its assumptions used in developing the various forecasts.

Market information provided in the study will cover 10-year history (2009-2019) and 15-year forecast (2020-2035) for the following geographies:

- North America
- Europe
- Asia
- Middle East and Africa
- Rest of the World
Products addressed will include:

- **Butadiene**
  - Butadiene Rubber (BR)
  - Styrene Butadiene Rubber (SBR)
  - Acrylonitrile Butadiene Styrene (ABS)

- **Butylenes**
  - Butyl Rubber (IIR)
  - Methyl Tertiary Butyl Ether (MTBE)
  - Butene-1
  - MMA.
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3 Methodology

3.1 Proposed Approach and Methodology

Nexant has considerable experience in undertaking similar reports. The basic approach will be:

- Utilising experience from performing a similar role on a number of recent assessments including updates to our prior report.
- Utilising its global in-house databases on capacity/supply/demand/margins and pricing.
- Direct market research/fieldwork with end users, producers and other relevant bodies.
- Review of selected public domain sources to provide the latest view of market developments in selected countries.

Nexant has a strong track record in evaluating petrochemical and polymer markets. This experience, along with non-confidential information from previous studies, will be used for this report.

3.2 Market Analysis: methodology

Nexant has developed 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 2045. The integrated simulation model includes both the market dynamics of product flows and the economics of production costs, logistics, prices and profitability.

3.2.1 Capacity Availability and Forecasting

The model includes a full capacity database for every petrochemical producing plant in all the global regions to generate availability of petrochemical supply. The capacity listings include the production process, the consumption factors of all raw materials, the yield of the main product and any co-products, the capacity to produce and changes to the capacity due to expansions etc. The capacity to produce petrochemicals for existing and planned projects is continuously researched and crosschecked with industry participants. Announced new production plants and projects in the planning phase provide a guide on the likely capacity available in each region for the next five to eight years. Thereafter, new capacity is forecast based on likely investment strategies for the given macro-economic scenario being considered.

3.2.2 End-Use Consumption Forecasting

Consumption growth of methanol and other “end-use” intermediates may be related to economic activity in the consuming region. Consumption of end-use materials into the major economies is researched to determine the link between sectors of the economy and consumption of methanol and derivatives. Demand for a particular polymer or intermediate can be linked to the sum of the demand into each of the end-use sectors. Growth in each end-use sector is made up of four additive elements:

- Demand due to growth of the end-use sector.
- Demand due to penetration into the sector for new applications.
- Reductions in demand due to recycling, downgauging of polymers and substitution by other materials/polymers.
- Demand due to cyclical downstream inventory changes.
For less developed economies, where data on individual sectors of the economy is less readily available and where the “services” sector of the economy is a much lower proportion, GDP is a fair substitute for petrochemical demand drivers. In these regions the end-use growth is driven by the four elements but applied to a single economic driver.

### 3.2.3 End-Use Sector Growth

The demand due to growth in the end-use sector assumes that the existing application for each polymer/derivative grows at the same rate as the end-use sector. Thus, the end-use sector growth forecasts developed in the “Base Case” Scenario are applied to the individual consumption figures for each polymer or derivative and each end-use sector.

### 3.2.4 Penetration (New Application Growth)

Analysis of historic demand for each sector by means of curve fitting allows a curve of overall penetration to be developed. This reflects the maturity of a product.

Penetration growth rates can be negative and are added to the growth of the end-use market. A negative penetration, eSBR in car tyres, does not automatically mean that the growth of the polymer itself would be negative, as the end-use sector growth plus inventory growth may produce a positive overall rate.

### 3.2.5 Short-term Influences

An influence on chemical demand during the economic cycle is a transient demand swing caused by short-term pricing volatility. As demand starts to pick up buyers and sellers perceive the tightness coming, which in turn leads to price increases. The buyer then responds to expected price increases by increasing demand above expected consumption levels in the knowledge that any purchases made above immediate consumption will be at a lower price than that required for the subsequent purchase. The reverse occurs when price falls are expected.

These transient demand swings usually occur over a few months and so do not influence annualised demand estimates. They are driven by market perception and although predictable in a short-term forecast, they cannot be realistically forecast on a long-term basis such as that used in this analysis. Consequently, the Nexant model does not consider short-term demand swings due to price fluctuations.
### 3.2.6 Monomer Consumption Drives

Having forecast the regional consumption for each end-use the simulation model generates global production and trade of the end-use products and the monomers and feedstocks used to produce the end-use materials. The consumption of monomers and intermediates is related directly to the regional production of the downstream derivatives.

**Figure 6  Monomer Consumption Drivers (example ethylene)**

- Naphtha, NGLs, Gas Oil etc. Consumption
- Ethylene Production
- Propylene, C4s, Pygas, Fuel Production
- Derivative Production requirements
- Exports
- Imports
- Inventory Growth
- HDPE
- LDPE
- LLDPE
- EB/Styrene
- EDC/VCM
- EO/MEG
- VAM
- Other Uses

### 3.2.7 Production and Trade Forecasting

The simulation model incorporates a detailed logistics and trade model to allow integrated forecasts of global trade balances. The trade balances use demand forecasting, capacity availability and trade drivers to forecast global supply, demand and trade.

**Figure 3.7 Trade Considerations (Country to Country Net Annual Trade)**

1. Is consumption satisfied?
2. Is there surplus capacity to produce?
3. Are operating rates within expected limits?
4. Any political or physical limit to trade?
5. Which producer regions have a cost advantage?
6. Which producers are likely to show export aggression?
7. Is logistics capability available?
The Petrochemical Simulator simultaneously develops forecasts of regional consumption, production, imports, exports and inventory changes for all commodity petrochemicals in all countries/regions forward to 2045.

The Petrochemical Simulator is used by Nexant to develop its commodity petrochemical market dynamics and profitability forecasts. It is also used by Nexant’s clients to develop their own private forecasts under license from Nexant. Please contact Nexant if you would like to evaluate the use of the Petrochemical Simulator for your organisation.

3.3 Specific methodology used for the C4 value chain

A key challenge of the C4 sector is understanding differences in butadiene capacity and production. Historically markets have become very tightly supplied despite having sufficient butadiene capacity. This has resulted in price spikes but low operating rates. To better explain this phenomenon Nexant has developed its own methodology that focuses on estimating mixed C4 availability. Nexant’s analysis includes a detailed review of individual steam crackers to estimate feedstock slate, cracking severity and operating rate. This model generates estimates of C4 theoretical/maximum availability in the market and actual production estimates of butadiene and butylenes.

Figure 3.8 C4 Production and Availability

NB cracking light feedstocks, such as ethane, producers small volumes of mixed C4s. These contribute to theoretical and potentially availability. However across most sited these are not recovered and do not contribute to butadiene production.
4 Nexant Qualifications

4.1 Nexant Overview

For over 50 years, Nexant has provided clients with strategic advice underpinned by deep commercial and technical knowledge across the downstream oil, gas, chemicals, fertilizer and renewable industries. Nexant’s clients include major operating companies, financial institutions, investors and public institutions. The company has completed thousands of assignments in more than 100 countries.

Figure 9 Nexant Energy and Chemicals Advisory Locations

Staffed by over 150 sector specialists worldwide, Nexant consultants include engineers, chemists, economists and business leaders from industry. The global energy and chemicals advisory team brings together technical, commercial and financial skills to support clients in a wide range of assignment types. Nexant’s core services include:

- Strategy and business planning
- National and Regional Master Planning
- Lenders’ Independent market, technical and environmental consultant for project finance
- Merger & Acquisition support: industry commercial and technical advisor
- Market evaluations (including addressable market appraisal)
- Project planning and screening studies
- Feasibility studies and Technology Evaluations
- Process, Business and Cluster Benchmarking
- Expert witness and litigation support
Nexant is distinguished by its extensive knowledge and reputation in the industries it serves and its track-record for providing insight for its clients. This is achieved through Nexant’s:

- **Industry knowledge:** Nexant works exclusively in the downstream oil, gas, chemicals, fertilizers and renewable sectors and has insight, which is not available from more generalist advisors.

- **Proprietary data and industry reports:** Nexant manages a vast database of valuable industry data, which further enhances its proposition for clients. This includes Nexant market, technical, pricing and financial data. This information is compiled through regular dialogue with oil and gas, chemicals and renewables companies and continuously updated by Nexant consultants and is available for purchase through markets and technology subscription programs.

- **Proven methodologies:** Nexant’s methodologies for developing commercial and technical analysis are widely understood and respected by producers and financial institutions.

- **Technical capabilities:** Nexant is recognised for the technical and operational expertise of its consultants and the insight provided by the NexantThinking™ Process Evaluation/Research Planning (PERP) programme. Nexant regularly advises clients on the merits of alternative technologies and how operations can be improved.

- **Delivery execution:** Nexant’s assignments are often associated with high-profile capital projects and mergers and acquisitions – its deliverables to support these transactions are highly credible with both investors and financial institutions.
4.2 Project Experience in C4 Sector

Nexant has an extensive subscriptions program, which provide a wealth of data and insight; we note the following areas of experience and in-house knowledge associated with these programmes:

The Markets and Profitability program is comprised of the well-known Petroleum and Petrochemical Economics (PPE), PolyOlefins Planning Service (POPS), Strategic Business Analysis (SBA) and World Gas Analytics (WGAS).

**Markets and Profitability** tracks over 60 feedstocks, petrochemicals, polymers and fertilizers on an ongoing basis and provides regularly updated reports covering all commercial aspects of these global industries. The accompanying database, provide global data, analysis and forecasts in two major inter-related areas: Markets and Profitability. The main commodity petrochemicals are covered, including the C4/butadiene value chain.

**Technoeconomics – Energy & Chemicals (TECH),** formerly known as Process Evaluation and Research Planning (PERP): The TECH programme includes a number of special reports covering techno-economic evaluation of both established and emerging technologies in all commodity chemical areas including olefins, aromatics, and major downstream products. This series of reports provides a useful compendium of data and insight on technologies and their economics. Recent reports covering technologies relevant to the C4 value chain include:

- Butadiene/Butylenes
- Styrene Acrylonitrile/Acrylonitrile Styrene Butadiene (SAN/ABS)
- Bio-Butadiene
- Styrene Butadiene Rubber (SBR)
- On-Purpose Butadiene (2013).

4.2.1 Selected Direct Project Experience

- **Butadiene Market Study** Nexant was engaged by a major synthetic rubber producer to provide a market study evaluating the supply demand and trade of butadiene, feedstock availability for butadiene production (including dehydrogenation process and bioroutes), key drivers and developments for the butadiene derivatives focusing on rubbers and analyse relationship between butadiene and cracker feedstocks.

- **Market and technology study.** A multinational petrochemical producer engaged Nexant to help it assemble, in one spreadsheet, market and technology information for C4, C5, C7, and C9 products and their derivatives. For selected products, Nexant provided historical and forecast global and regional supply/demand and trade-flows, average prices, major producers, breakdown of main applications, process technologies, production economics, technology owners/licensors, known risks, regulatory issues, and a market status for China.

- **C4 Growth Strategy Project.** For a chemical major in Saudi Arabia, Nexant profiled the C4 and derivative markets, highlighting key trends and growth opportunities. Recommendations included how to best exploit the firm’s leading technology in a key C4 derivative.

- **Value Added Options to C4’s streams (Deep Dehydrogenation)** Nexant was retained to provide a technical analysis, market dynamics, cost competitiveness and economic evaluation. Products covered in this report included butylenes, butene-1 and C4 products and derivatives.

- **Adding Value to Crude C4s** A refining company was interested in building a naphtha cracker to produce ethylene and propylene. Nexant was retained to investigate potential downstream derivatives products from the mixed C4 and pygas co-product streams. The study included a screening analysis to evaluate the opportunities to add value to crudes C4s and pyrolysis gasoline, in order to define the processing chains that can be considered in the cracker project and a feasibility study for the overall complex.
• **C₄ Feedstock Strategy.** For a chemical major in North-Western Europe, Nexant advised on a strategy to identify, secure and gain competitive access to strategic raw materials (crude C₄, butadiene and isobutylene). The report covered hydrocarbon outlook, petrochemical supply and demand analysis, technology options for alternative routes to butadiene, global and regional C₄ and butadiene supply and pipeline supply infrastructure in North America and Europe.

• **Qatar butane cracker update.** For a holding company, Nexant provided an evaluation of the financial attractiveness using a discounted cash flow (DCF) model for a proposed butane cracker project in Qatar comprising of seven distinct units: ethylene, HDPE, polypropylene (PP), isobutylene, polyisobutylene (PIB), isoprene, and butyl rubber.

• **C₄ Masterplan.** For an integrated gas, refining and petrochemicals company, this project covered the exploitation of gas derived mixed butane reserves to develop an integrated butanediol business with butadiene, butylenes and derivatives (involving high severity deep dehydrogenation) and isobutylene/mixed butylenes (involving low severity dehydrogenation). The project covered market and product screening, technology assessment, price forecasts, project financials and the development of C₄ development roadmap.

• **Feasibility study of C₄ complex.** Nexant was retained by a holding company operating in the Middle East to perform a feasibility study of a C₄ complex. Among the products considered were MMA/PMMA, butyl rubber and polyisobutylene.

• **C₄s Market Study** Nexant provided a market analysis of the C₄s and derivatives (e.g., MMA/PMMA, MTBE) business. The client was evaluating expanding its operations into this business. The study comprised supply/demand/net trade balances and prices forecast.