

The background of the slide is a photograph of an industrial refinery. It features several tall, silver-colored distillation columns and a complex network of pipes and metal walkways. The sky is a clear, bright blue. The image is partially obscured by a white text box on the left side.

IHS CHEMICAL

C₅ Value Chain Study: From Cracker to Key C₅ Derivative Applications for Isoprene, DCPD and Piperylene

Special Report Prospectus

IHS Chemical Prospectus



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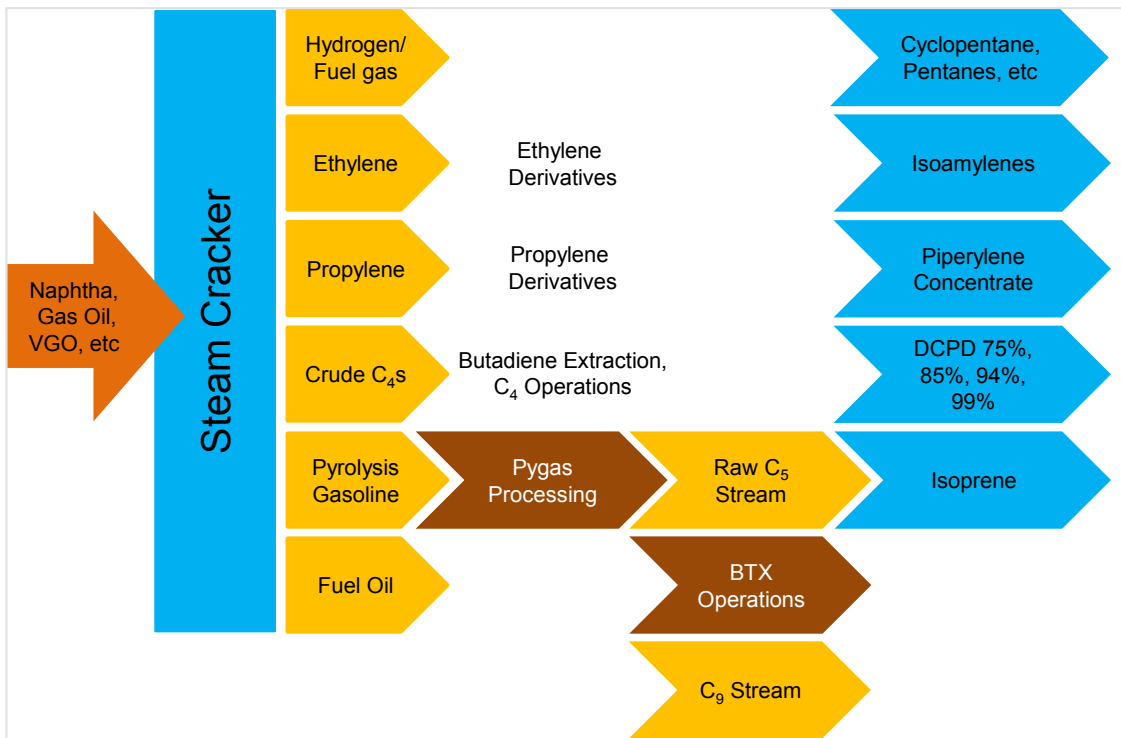
Introduction

What are C₅ Petrochemicals?

Steam cracker operators based on liquids cracking today co-produce a crude C₄ stream from which butadiene is often separated by extractive distillation ahead of a number of processes to valorize each component; isobutylene, butene-1, mixed butanes, etc. This often involves the exploitation of refinery-petrochemical integration to maximize value to each component and by-product stream. While C₄s processing is well understood, for many companies C₅ remain an untapped source of value.

The figure below illustrate where the C₅ stream can be sourced and what components can be found therein.

Where C₅ Components Can be Found in the Cracker



In the steam cracker envelope, the C₅ stream is separated from pyrolysis gasoline. In many cases it is hydrogenated either in a single stage to mainly C₅ olefins or completely to pentanes. In many cases a value-added opportunity for the cracker operator may be missed.

While a low crude price prevails at the time of writing, medium to long term IHS projections of Brent crude suggest a return to higher values and in such a case where liquids crackers compete against ethane/NGL crackers, the spotlight once more will fall on adding maximum value to every stream the liquids cracker can produce.

By way of example, a liquids cracker capable of producing 1.0 million metric tons per year of ethylene can co-produce around 120 thousand metric tons per year of so-called raw C₅ stream. This will contain around 18% isoprene, 22% cyclopentadiene and 15% piperylene. Compositions vary with feedstock and severity. Such a stream can supply a complex to generate monomers to in turn support several downstream industries.

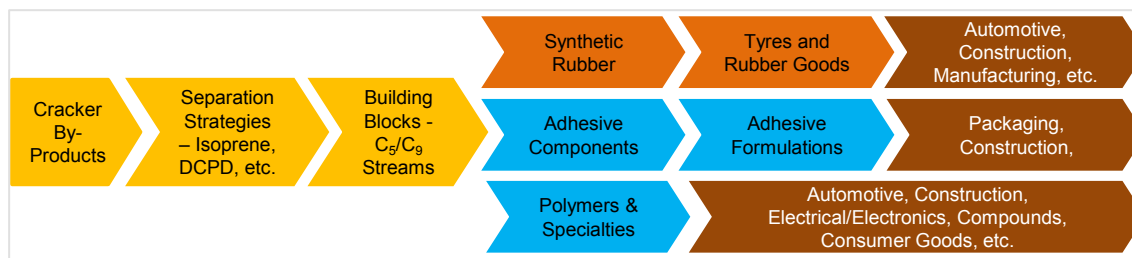
What Industries do C₅ Petrochemicals Supply?

At a high level the C₅ stream provides a link between the cracker and a number of downstream industries, both commodity and specialty. In terms of industries served, there are several ranging from synthetic rubber production (mainly via isoprene) through adhesive building blocks and formulations (via hydrocarbon resins, thermoplastic elastomers, etc.) and a range of specialties, fine chemicals, performance plastics, etc.

A Simplified View of the C₅ Value Chain

The ultimate industries served vary from the likes of automotive, e.g., tires, hose, belt, fabricated items and sealants, through the likes of construction, electronics, consumers goods, through to personal care, e.g., fragrance chemicals. The chain can also be extended to nutraceuticals like vitamins, antioxidants, etc. The portfolio of applications served is considerable from large volume applications for monomers like isoprene to polyurethane blowing agents based by cyclopentane.

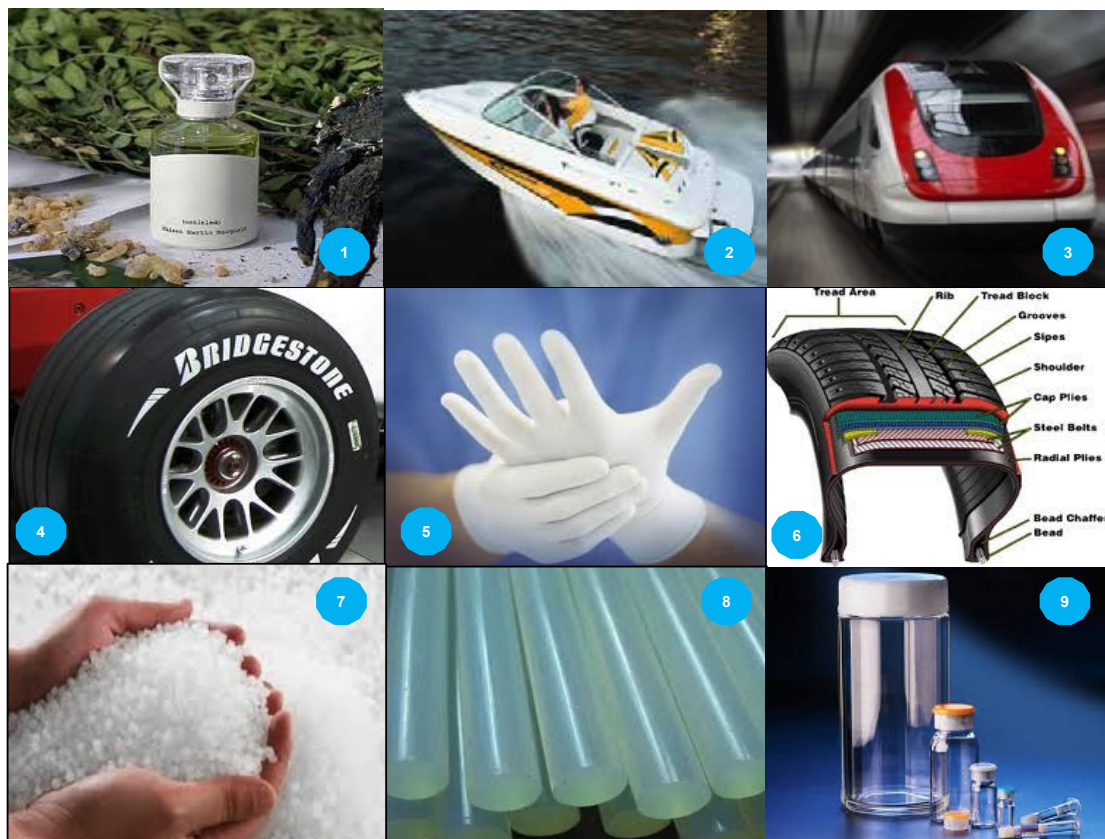
The following figure provides a view of a small sample of major downstream applications in the C₅ petrochemicals industry.



Examples of C₅ Chemical Derivatives

In this case the figures above relate to the following

1. Galaxolide® (and equivalents) – a fragrance with a clean sweet musky floral woody odor used in detergents or conditioners as well as fine perfume brands. Galaxolide® includes isoamylene as one of its raw materials.
2. Unsaturated polyesters (“UPR”) based on dicyclopentadiene (“DCPD”) used in the recreational marine industry with a high quality surface finish.
3. UPR used for mass transportation can also include DCPD-based systems.
4. High performance tires contain polyisoprene rubbers
5. Medical gloves and other hygiene products contain special grades of polyisoprene
6. The inner liner of a car tire is made of halogenated butyl rubber, itself made from isobutylene and isoprene.
7. A so-called “Waterwhite” hydrocarbon resin (“HCR”) made from DCPD is used for adhesives formulations for many hygiene products



Sources: Bridgestone, Kraton Polymers, tyres.about, Bostik, Topas, Campion and CCR Composites

8. Other types of HCR, derived from piperylene may be used in hot melt adhesives systems
9. Specialty transparent plastics based on DCPD-derived cyclic olefin copolymers (“COC”) serving applications like pharmaceuticals packaging through to electronics.

The range of applications that IHS Chemical covers in this study is considerable and links in with other parts of IHS including IHS Automotive, IHS Technology (electrical/electronic) IHS Energy Insight (renewable energy development), etc.

Accessing C₅ Petrochemicals

As with the process of crude C₄s, a strategy is needed to access the building blocks contained in the C₅ stream. It is typical to heat treat the C₅ stream and this converts contained cyclopentadiene into its dimer, DCPD. This is usually separated as a stream with a purity ranging from 75%-85%. Various processes, but simple and complex can provide a high purity DCPD (92%-94% concentrate) and a 99% stream.

The next step is generally to separate the piperylene as a 60%-65% concentrate via some form of fractionation. The stream can include some isoamylenes (2-methylbutene-1/2-methylbutene-2) by design and process control.

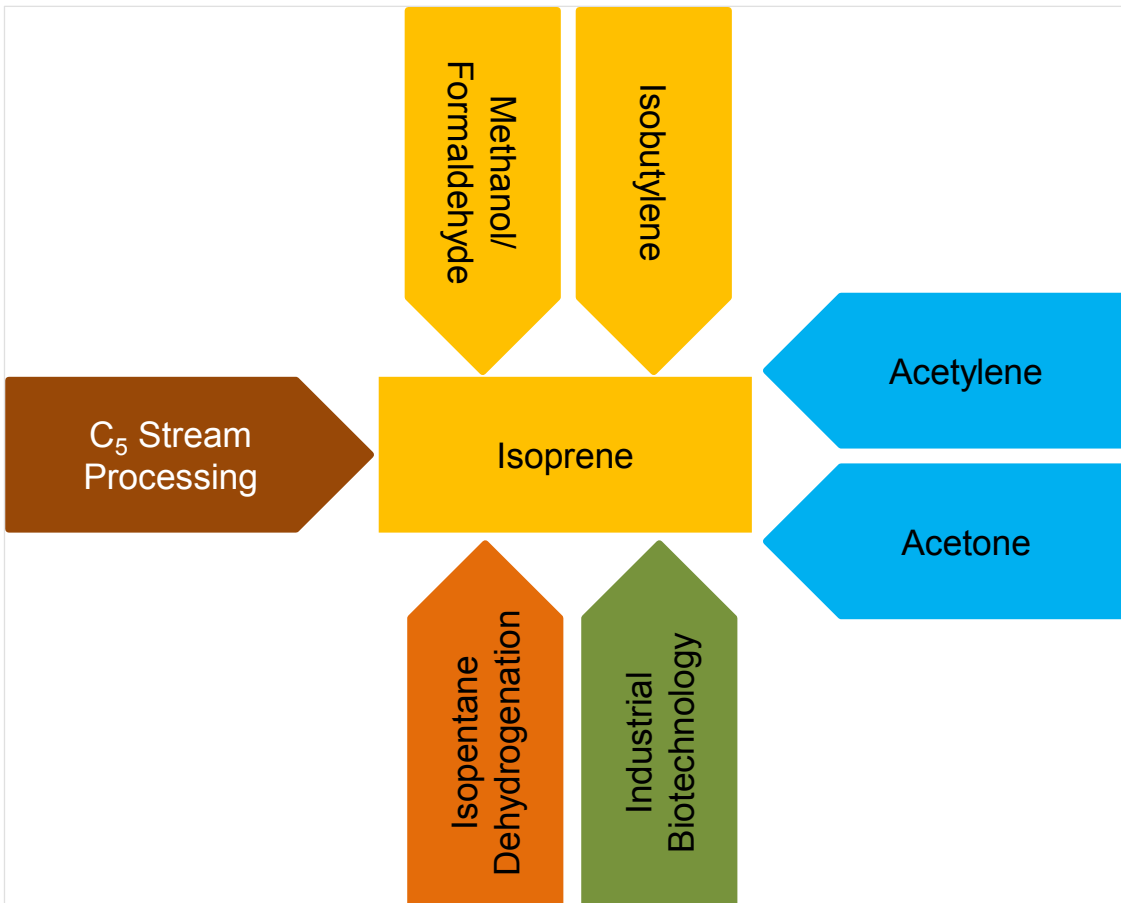
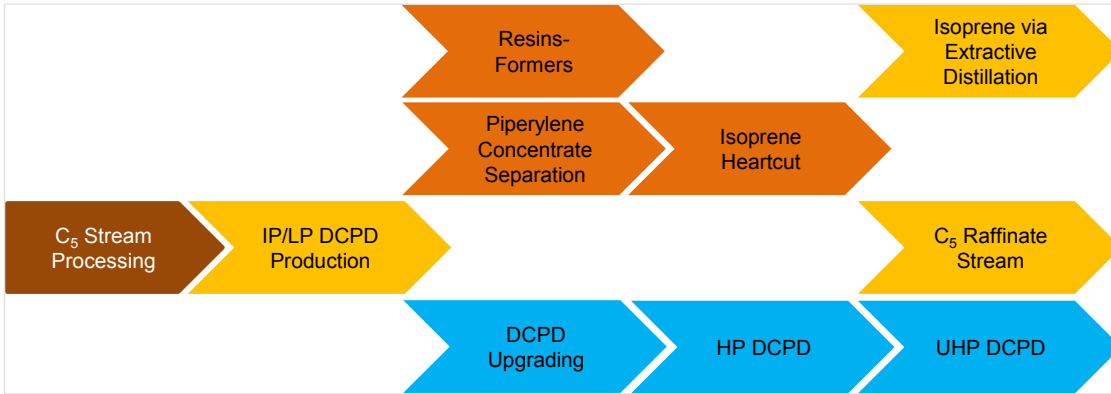
The by-product of this process is an isoprene concentrate from which isoprene can be separated by extractive distillation in much the same way as butadiene is separated from crude C₄s.

What remains is an olefin-rich stream where isoamylenes can be converted into TAME (tertiary-amyl methyl ether) for gasoline blending or for subsequent back-cracking to obtain a pure isoamylenes stream. Other pentenes have been used for fine chemical synthesis.

Hydrogenation of residual pentanes provides pentanes including cyclopentane. This and other pentanes are used for blowing agents for polyurethanes, expanded polystyrene, etc.

Over the years, different routes to C₅ petrochemicals have been commercialized with particular focus on isoprene. In the Former Soviet Union, isoprene for polyisoprene was made synthetically via the dehydrogenation of pentane and this is still practiced today.

A Simplified View of Typical C₅ Operations



A Simplified View of Alternative Routes to Isoprene Monomer

The isobutylene-based route also operates today and historically the acetylene-based process has operated in Italy and South Africa. The rise in the coal-based chemicals industry in China has provided acetylene via calcium carbide for chemical conversion and could potentially attract investment in the future. More recently with perceived longer term strengthening in crude oil price with only modest increasing projected in biomass pricing, companies have sought to commercialize a bio-based process for isoprene.

Issues Impacting the C₅ Petrochemicals Industry

In North America the advent of shale gas has led to a reduction of liquids cracking for ethylene production, replaced by the cracking of ethane and other natural gas liquids. This has severely reduced the availability of C₅ streams for separation units and derivatives industries. In Europe and Asia liquids cracking still dominates ethylene production. However, in Europe a number of companies with coastal cracker locations are looking to ship shale gas-derived ethane from the U.S., potentially reducing the future availability of C₅ streams in that region too.

In response to these deficiencies and the need to develop its own C₅ petrochemicals industry, a very large program of capacity expansions has been and continues to be undertaken. Other countries like Singapore and Taiwan have also developed C₅ processing infrastructure to serve local developments, e.g., the start-up of Lanxess butyl rubber operation in Jurong island.

When looking at downstream markets, the renewable energy business constantly looks at new materials for wind energy platforms and there has been renewed interest in using reaction injection molding (“RIM”) techniques for wind blade and tower composite production using poly-DCPD based on ultra-high purity DCPD feedstock.

In the adhesive industry, move-away from solvent based systems to water-based and hot melts continues. There is the additional issue of continued inter-competition between synthetic resin based on piperylene and natural systems based on rosin esters. As the first figure illustrated another stream is derived from pyrolysis gasoline called the C₉ stream. This stream, often called C₉ resin oil, too is used for hydrocarbon resin production with different compatibility with other adhesive formulation materials. Piperylene and C₉ resin components can also be copolymerized. This report therefore includes a discussion of the C₉ opportunity alongside the C₅ petrochemical opportunity.

Study Objective

IHS Chemical provides detailed analysis of steam cracker and derivative business through its extensive annual and monthly services covering ethylene, propylene, C₄s and aromatics. This Special Report works towards completing IHS Chemical's coverage of steam cracker envelope with comprehensive view of the C₅ business to provide a detailed understanding of C₅ component derivative market dynamics, pricing dynamics, technology, manufacturing costs to provide key insight of how to enter and participate in this business with a view to adding maximum value to the steam cracker envelope.

Study Scope

Market Dynamics for C₅ Petrochemicals

In this report IHS Chemical will provide market dynamics for the major C₅ petrochemicals – isoprene, DCPD (according to purity), piperylene concentrate, isoamylenes, pentanes and where pertinent for completeness, C₉ resin. The regions covered will include: North America, South America, Western Europe, Central Europe, the CIS and Baltic states, the Middle East, Africa, China, Japan, Other Northeast Asia, Southeast Asia and Oceania.

Market dynamics will cover consumption by end-use, current and future supply/demand, capacity, inter-regional trade and balances for the 2009 to 2030 time period.

Pricing Dynamics for C₅ Petrochemicals

IHS Chemical will provide tri-regional price and margin forecasts for the major C₅ petrochemical components –isoprene, DCPD (according to purity), piperylene concentrate, isoamylenes, pentanes and where pertinent for completeness, C₉ resin oil.

IHS Chemical in collaboration with IHS Energy Insight will develop and discuss alternate values for C₅ streams that form feedstocks, intermediates and by-products from this industry. Such streams can find use in the refinery, e.g. for gasoline blending after stabilization through hydrogenation and other refinery processes such as isomerization. It is also possible to determine a value for various C₅ streams with respect to hydrogenation followed by recycle co-cracking.

Downstream Industries Review

In this project IHS Chemical will provide a detailed review of downstream industries where C₅ petrochemicals are consumed. IHS Chemical analysis will cover market dynamics, capacity developments, inter-regional trade and a review of strategic issues. To support this, IHS Chemical will review relevant developments in downstream industries that reflect up the C₅ petrochemicals value chain. Relevant derivative markets will be reviewed as follows:

- Isoprene Derivatives:
 - Polyisoprene – high cis grades and trans 1,4 grades
 - Thermoplastic elastomers
 - Butyl rubber
 - Specialties – flavor and fragrance chemicals, epoxy resin hardening agents, specialty elastomers – styrene-isoprene-butadiene, vitamins, nutraceuticals, lubricant additives, etc.
- Low /Intermediate Purity Dicyclopentadiene
 - Hydrocarbon resins – waterwhite and non waterwhite
 - Unsaturated polyesters
- High Purity Dicyclopentadiene
 - Ethylidene norbornene
 - EPDM elastomers
 - Flavor and fragrance chemicals
 - Fine chemicals
- Ultrapure Dicyclopentadiene
 - Poly-DCPD RIM Systems
- Piperylene Concentrate
 - Aliphatic hydrocarbon resin
 - Aromatic hydrocarbon resin from C₉ resin oil
 - Hybrid resin systems
- Isoamylenes
 - Aliphatic hydrocarbon c modification
 - Polymer antioxidants
 - Flavor and fragrance chemicals
 - Specialty chemicals

- Pentanes
 - Expanded polystyrene
 - Polyurethane foams
 - Refrigeration chemicals

Value Chain Considerations

As indicated in the introduction, the C₅ petrochemical business serves many different downstream IHS Chemical will opine on relevant developments in the following industries and their upstream impact on the C₅ business:

- Tire and automotive focused on regional growth taking into consideration environmental legislation that impacts tire design and composition as well as the wider use of plastics in the automobile. This is relevant to not only elastomers in tires and automotive underhood, but also adhesive systems, etc.
- The automotive industry consumes considerable volumes of fiber-reinforced unsaturated polyesters. Lightweighting legislation is driving further plastics use in automotive that could one hand accelerate the recovery of the UPR industry, but on the other hand, trends in automobile design and the use of the same components across multiple models could leads to the increased use of thermoplastics over thermosets where matching performance is possible.
- Adhesives in general with continued pressures on reducing VOCs and more aggressive environmental legislation. Formulations and performance demand impact components such as hydrocarbon resins and with that the continued inter-competition of natural and synthetic resins.
- Renewable energy is important as this impacts certain growth industries like epoxies and emerging materials for wind turbines, e.g. poly-DCPD. Wider interests relate to adhesive systems for solar system production and assembly.

Other relevant industries under consideration will include

- Electric/Electronic – impacts UPR, epoxy hardening agents, COCs, etc.
- Flavor and fragrances – impacts fine chemicals derived from isoprene, DCPD and isoamylenes.
- Construction, marine, consumers goods, etc., - impacts, UPR, EPDM, etc.

Manufacturing Costs and Technologies for C₅ Petrochemicals and Derivatives

IHS Chemical will provide manufacturing costs for the following processes for the regions of the United States, Western Europe, the Middle East, Japan and China:

- Isoprene monomer
 - Extractive distillation from isoprene heartcut
 - Complete C₅ complex with low purity DCPD and piperylene concentrate by-products
 - Synthetic isoprene
 - Isobutylene/methanol
 - Acetylene (coal and gas-derived)/acetone
 - Isopentane dehydrogenation
 - Bio-based isoprene from captive sugars and PFAD¹
- Dicyclopentadiene
 - Low/intermediate purity
 - Upgrading to high purity
 - Upgrading to ultra-pure via DCPD cracking, CPD refining and controlled redimerization
- Piperylene concentrate
 - Superfractionation from CPD-depleted C₅ streams with isoprene-rich by-product stream
 - Commentary on synthetic piperylene from pentanes
- Isoamylenes
 - Via etherification to TAME and back-cracking
 - Commentary on potential 3-methyl-butene-1 production

¹ PFAD=Palm oil fatty acid distillate

Manufacturing costs will be accompanied by a description and discussion of the process technology. Samples of relevant cost tables and figures can be found later in this brochure. IHS Chemical will also provide costs and process information for selected C₅ petrochemical derivatives as follows:

- Isoprene monomer
 - High cis polyisoprene
 - SIS/SEPS thermoplastic elastomers
 - Butyl rubber

- Dicyclopentadiene
 - Hydrocarbon resins for ink applications by thermal polymerization
 - Waterwhite resins via hydrogenation
 - Unsaturated polyesters – conventional from PAN and DCPD
 - Ethylidene Norbornene
 - EPDM Rubber based on ENB and DCPD
 - Poly-DCPD RIM Compounds

- Piperylene concentrate
 - Aliphatic hydrocarbon resins
 - Aromatic hydrocarbon resins (from C₉ resin oil)
 - Mixed aliphatic-aromatic copolymer hydrocarbon resins
 - Commentary on synthetic piperylene from pentanes

- Isoamylenes
 - C₅-based polymer antioxidants

Key Questions

As part of this study, IHS Chemical will review the strategic issues impacting the C₅ petrochemicals industry. The key questions the study seeks to answer are as follows:

- What is the impact of shale gas and the potential movement in Europe to light feedstocks?
- What is the impact of the Chinese economic slowdown?
- What is the impact of octane needs in China and the valuation of C₅ streams?
- What is the impact of future developments in tire technology on the isoprene chain?
- What is the impact of natural synthetic hydrocarbon resin inter-competition?
- What is the best way to add maximum value to the petrochemical C₅ stream?
- What is the most appropriate strategy to enter the C₅ petrochemicals business?
- What is the impact on the competitiveness of steam cracker operations?

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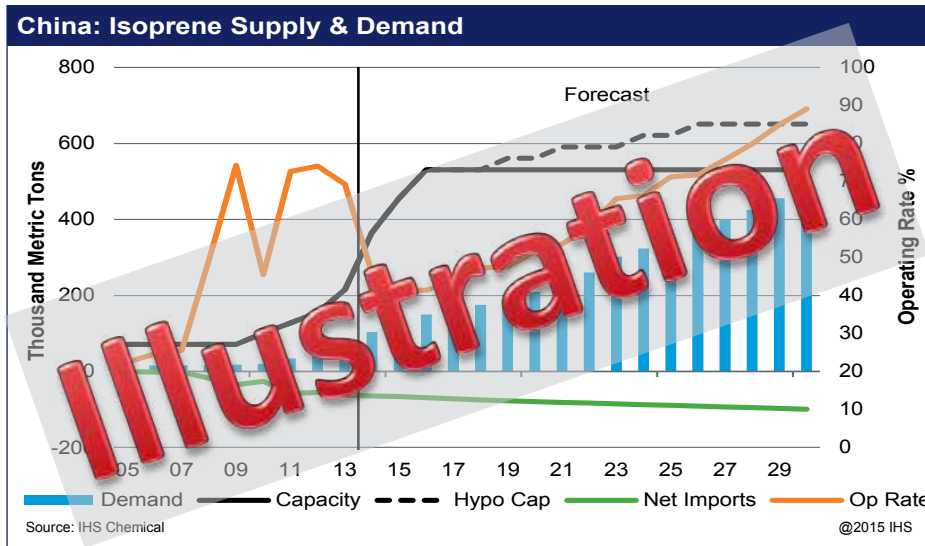
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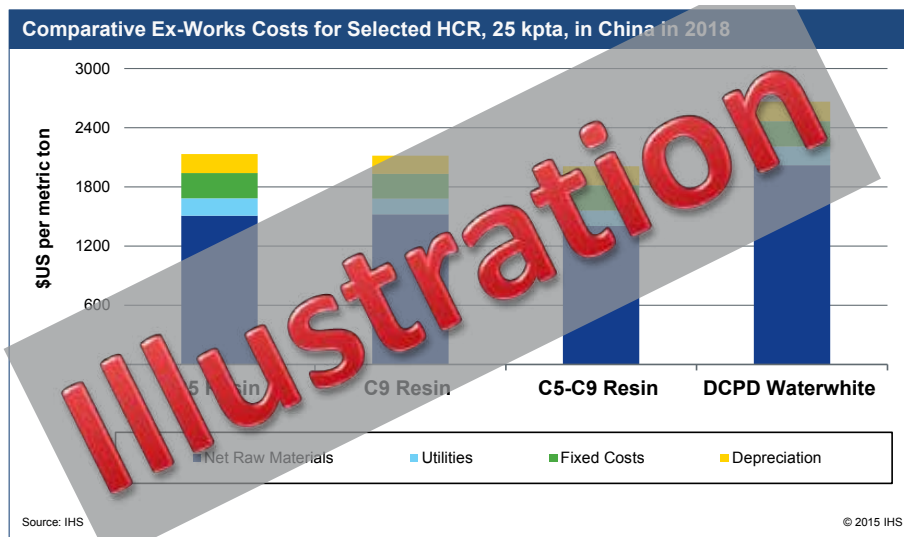
Deliverables

In addition to the final report in narrative form (PDF), this report includes online access to data tables in Excel format. Clients also receive access to IHS Chemical C₅ and derivative experts, who can provide additional explanation about market fundamentals and trends discussed in the report.

Sample Supply/Demand Figure: Isoprene in China



Sample Cost of Production Summary: Hydrocarbon Resins



Sample Cost of Production Estimate: Isoprene from an Isoprene Heart-cut

Cost of Production Estimate for: Isoprene Monomer from Isoprene Heartcut via Extractive Distillation, Q3/2014							
Capacity, 000 tons per year	36.00		Capital Investment	ISBL, \$MM	54.7		
Operating rate	95%			OSBL, \$MM	44.8		
Production, 000 tons	34.2			Total	99.5		
	Consumption Factors	Consumption Units	Price \$US per ton	Price Units	\$US per ton	Annual Cost, \$MM	Comments
Raw Materials							
Isoprene heartcut (alternative value)	1.08	tons/ton		\$US/ton	761	26.0	
Make-Up extraction Solvent	0.00	tons/ton	14	\$US/ton	1.4	0.05	
Inhibitor	1.00	\$/ton	20	\$US/ton	20.1	0.7	
Total Raw Materials				\$US/ton	783	26.8	\$Million
By-Product Credits							
C ₅ stream for Gasoline blending	0.08	tons/ton	743	\$US/ton	56	1.9	
Total By-Product Credits				\$US/ton	56	1.9	\$Million
Total Net Raw Materials				\$US/ton	727	24.9	\$Million
Utilities							
Cooling Water	169.80	tons/ton	0.04	\$US/ton	19	0.7	
Electrical Power	6.86	kWh/ton	0.06	\$US/kWh	7	0.2	
Inert Gas	2.95	Nm ³ /ton	0.09	\$US/Nm ³	0	0.0	
Process Water	0.34	tons/ton	0.36	\$US/ton	0	0.0	
Medium Pressure Steam	14.30	tons/ton	20.80	\$US/ton	297	10.2	
Total Utilities				\$US/ton	324	11.1	\$Million
Total Variable Cost				\$US/ton	1051	35.9	\$Million
Direct Fixed Costs							
Manpower per shift	3.0	Shifts	5				1 shift USGC Shift pattern
Average Operator Cost			46800	\$US/manyear	21	0.7	
Maintenance Materials (ISBL, %)	2.4%				38	1.3	
Operating Supplies (Operator cost, %)	10.0%				2	0.1	
Maintenance Labour (ISBL, %)	1.6%				26	0.9	
Control Laboratory/QC (Operator cost, %)	20.0%				4	0.1	
Total Direct Fixed Costs				\$US/ton	91	3.1	\$Million
Total Direct Costs				\$US/ton	1142	39.0	\$Million
Indirect Fixed Costs							
Olant Overheads (Labour costs, %)	80.0%				40	1.4	
Local Tax and Insurance (ISBL&OSBL, %)	1.6%				47	1.6	
Total Indirect Fixed Costs				\$US/ton	87	3.0	\$Million
Total Cash Cost				\$US/ton	1228	42.0	\$Million
Post Production Costs							
Depreciation - ISBL, %	10.0%				56	1.9	
Depreciation - OSBL, %	0.0%				23	0.8	
Plant Age-Related Weighting, %	0.0%						
Total Depreciation				\$US/ton	79	2.7	\$Million
Total Ex-Works Costs				\$US/ton	1307	44.7	\$Million
Supporting Costs							
SG&A	0.5%				85	2.9	Factored off capex/opex
Supporting R&D	2.0%				105	3.6	Factored off capex/opex
Delivery Freight	1.00		65		65	2.2	
Total Supporting Cost				\$US/ton	256	8.7	\$Million
Built-Up Delivered Cost				\$US/ton	1563	53.4	\$Million

Source: IHS Chemical estimates based on the sources listed in the table.

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Methodology

Supply and Capacity

The supply and capacity analysis required for this study will leverage the existing global capacity database of C₅ operations by process types components that IHS Chemical maintains. Using the C₅ component capacity database as a starting point, the study team will identify opportunities C₅ building blocks production and conversion based on the experience and understanding of the marketplace.

IHS Chemical experts will then utilize their industry connections along the whole supply chain to:

- Verify the location and status of C₅ complexes and components that are making each derivative currently and any expansion plans
- Discover which producers are planning new developments in C₅ petrochemicals and derivatives
- Seek feedback on process economics and new licensees
- Estimate future utilization rates and identify likely source for capacity addition



IHS Chemical experts plan to contact the following producers and consumers for the study

- Current major C₅ players will include
 - Braskem
 - Dow Chemical
 - ExxonMobil
 - Formosa Chemical
 - JSR
 - LG Petrochemical
 - LyondellBasell
 - Mitsui
 - Nizhnekamsk Petrochemical Combine
 - Shell Chemicals
 - Texmark
 - Togliattikauchuk JSC
 - Zeon Corporation
- Technology licensors
 - GTC
 - Axens

Demand

Leveraging existing IHS database of global demand by end use and region, the study team will analyze historical trends, key demand drivers and their impact on demand forecast.

The study team will then contact key producers, end users, licensors, equipment manufacturers, and trade organizations to

- Check market size estimations and understand changing dynamics
- Verify relative size of end uses
- Explore interpolymer competition and its impact on demand by user segment
- Identify demand and demand drivers



For this part of the study, IHS Chemical Experts plan to make the following contacts globally:

– Isoprene

- Dexco Polymers
- Fuso
- Kraton Polymers
- Lanxess
- Maoming Zhonghe Huasu Co., Ltd.
- Polynt
- Sinopec Baling Petrochemical Co., Ltd.TSRC
- Goodyear

– DCPD

- Eastman Chemical
- Kolon Chemical
- Maruzen PC
- Rutgers
- Neville Chemical
- Ineos Oxide
- Lanxess
- Kumho
- Versalis
- Sanyo Petrochemical
- Polyplastics
- Mitsui Chemical
- Metton® LMR
- Materia
- Telene
- International Flavors and Fragrances
- Reichhold
- Ashland
- Scott Bader
- DSM Resin
- Dainippon Ink Chemical

– Piperylene/ Isoamylenes

- Ineos
- Givaudan
- SIIG
- Etc.

Production

IHS Chemical has created a proprietary internal model that estimates volume of annual C₅ component production at each individual steam cracker and on-purpose production unit. The production numbers are informed by survey data collected by IHS Chemical, conversations with industry players, publicly available data resources, and internal IHS Chemical yield models. IHS Chemical also takes into consideration site-specific integration and intra/inter-regional movements of various C₅ streams, for example there is considerable movement within mainland China and within countries in Asia. Information from 2009-14 represents IHS Chemical's best understanding of previous markets, while 2015-30 is forecast based on announced and anticipated changes in production.

Trade

IHS Chemical has created an internal model of trade flow between regions, in which the C₅ component produced by each unit is sent to the consumption facility or facilities that IHS Chemical believes to be that producer's customer, or a likely customer of the production facility. Exact trade volumes represent IHS Chemical's best understanding. IHS has recently acquired major trade advisory service organizations including GTIS and PIERS. These organizations within IHS will support the trade analysis component of this study.

Technology and Production Costs

IHS Chemical has developed models for the various monomers, intermediates and polymers in this study based on process simulation in ASPEN® linked to various capital and operating cost modules to develop capital cost estimates and operating cost estimates covering raw materials, catalysts, utilities, fixed costs, etc. through primary and secondary research, e.g., through interviews with licensors, IHS Chemical has verified and will verify such models to ensure they are reasonable representations of commercial operations. No confidential information will be used in these models.

Qualifications

Through its ongoing day to day work in the olefins sector, IHS monitors and evaluates cracker operations worldwide in terms of feed slate and integration, including upgrading operations for by-product streams including raw C5s and C9+ streams from liquids crackers in particular.

CEH – Chemical Economics Handbook

IHS Chemical already provides a number of market-focused on the C₅ value chain, including

- Butyl Rubber
- Cyclopentadiene/Dicyclopentadiene
- EPDM Elastomers
- Epoxy Resins
- Isoprene
- Polyisoprene
- Styrene Block Copolymers
- Unsaturated Polyesters

CEH reports are updated every 2 years.

SCUP – Specialty Chemicals Update Program

IHS Chemical also provides a number of industry-focused study focused on the downstream industries served by C₅ components including

- Flavor and Fragrance chemicals
- Coatings
- Adhesives and Sealants

SCUP reports are updated every 2 years.

PEP– Process Economics Program

IHS Chemical also provides a number of technology-focused studies for C₅ components and their derivatives including

- Isoprene Extraction Economics
- Biobased Isoprene
- Synthetic Isoprene
- Styrene Block Copolymers
- Polyisoprene Elastomers
- Butyl Elastomers
- Aroma Chemicals
- Dicyclopentadiene
- EPDM Elastomers
- Ethylidene Norbornene Synthesis
- Unsaturated Polyesters
- Cyclic Olefin Copolymers
- Selected Agrichemicals – Herbicides/Pesticides
- Flame Retardants
- Petroleum Resins

Single-Client Consulting Work

IHS Chemical has also performed various single-client consulting work that includes analysis of the C5 industry. The following projects are a few examples of the single client work that IHS Chemical has conducted in the last couple years with extensive C5 analysis.

- **C5 Complex planning** - For an emerging petrochemicals player in Asia, a feasibility study for an integrated C5 complex covering feedstocks, technology, pricing, financials, market entry, etc.
- **Market Analysis for C4 and C5 chemicals** - For a leading Saudi-Arabian-based petrochemical producer seeking to expand its portfolio into isoprene and derivatives from isobutylene (AS well as LAB and 4MP1), The analysis covered global market opportunity, pricing, derivative opportunity, cost competitiveness, process technology, market entry planning and financial analysis.
- **China C5 chemical opportunity analysis** - For a leading German/global-based chemicals producer with major production assets in China a detailed appraisal of the Chinese opportunity for isoprene, DCPD, piperylene, and other C5 components. The analysis covered market opportunity, pricing, derivative opportunity, cost competitiveness, process technologies, site integration, customer base analysis, market entry planning and financial analysis.
- **Asia Isoprene market analysis** - For a leading Japanese isoprene producer, a detailed appraisal of the Asian market opportunity for isoprene covering markets by country, pricing, customer base analysis, market entry planning and financial analysis.
- **Isoprene market and economics analysis** - For a company developing green/bio-isoprene, a detailed analysis of the global isoprene business opportunity. The analysis covered global market opportunity by region, derivative opportunity, pricing, cost competitiveness, process technology, market entry planning and financial analysis.
- **Petrochemical opportunities** - For a major FSU-based petrochemical producer seeking to extend its portfolio, a detailed appraisal of a wide range of petrochemical products and derivatives, including the C₅ chain with synthetic isoprene, polyisoprene and butyl rubber. The analysis covered market opportunity by region, derivative opportunity, pricing, cost competitiveness, process technology, market entry planning and financial analysis.
- **EMEA Cracker Dynamic Study** – Client wished to understand the impact of the move from heavy to lighter cracker feedstocks in EMEA on the availability of C5 and C9 co-products for use in the adhesives and hydrocarbon resins industry. The study reviewed the current and medium term feed slates for each cracker in EMEA, selecting the crackers that may potentially supply C5 and C9 to the client. These crackers were then reviewed in more detail, profiling the level of integration for these crackers and commenting on the potential for these crackers moving to lighter feedstocks. In addition, IHS provided views on the availability of C9 resin oil, DCPD, piperylene, styrene and AMS in the EMEA region in the longer term.
- **Bio-based Isoprene Due Diligence** - For an industry player in renewables chemicals and natural oils, the commercial and technical due diligence of a bio-based technology for isoprene covering technical appraisal, scale-up risk assessment, cost competitiveness, market opportunity and business financials.

Study Team

Dr. Mark Morgan – Managing Director

Dr. Mark Morgan has 20 years of experience in Chemicals Consulting, e.g. with Chem Systems, and prior to that a career in BP Chemicals in new technology development/R&D. Mark has lead multiple projects in the C5 and related chemicals business including:

- **Commercial and technical due diligence of a European hydrocarbon resin producer**—covering production technology, technical audit, asset valuation, business strategy, market dynamics, business financials, etc.
- **Global hydrocarbon resins market dynamics analysis**— For a leading European and US producer of C9-hydrocarbon resins, a global market study focused on C5 and C5-C9 resins. The analysis covered consumption by end-use, capacity, inter-regional trade, operating rates, price and profitability with some insight into production technologies.
- **Hydrocarbon resins market dynamics analysis in Asia**— For a potential joint venture in Asia between a leading European producer of C9-hydrocarbon resins and a Korean producer of C9, C5 and C5-C9 resins, the in-depth analysis for the Asian market covering consumption by end-use, capacity, inter-regional trade, operating rates, price and profitability with some insight into production technologies.
- **Petrochemical C5 and derivative opportunities in India in the private sector**— For a leading Indian private sector oil refining and petrochemicals producer, the feasibility study for the production of all C5 hydrocarbon products and major derivatives covering, isoprene rubber, styrene block copolymers, butyl rubber, full range of DCPD and IPS based hydrocarbon resins, unsaturated polyesters, cyclic olefin copolymers, etc. The analysis covered market dynamics, price and profitability, capacity, technology, manufacturing cost, integration options, etc.
- **Global review of the C5s industry** – for a world leader petrochemicals with tri-regional olefins manufacturing capacity, a detailed review of the C5 business for all fractions from isoprene to cyclopentane, covering market dynamics, price and profitability forecasts, process technology, market entry strategy, site-specific implementation plans, derivative technology and manufacturing cost.
- **Global review of the C5s and derivatives industry** – for a major cracker operator in Taiwan with an extensive rubber production portfolio, a detailed review of the C5 business for all fractions from isoprene to cyclopentane, as well as derivatives including polyisoprene, butyl rubber, SIS/SEPS, hydrocarbon resins, unsaturated polyesters, EPDM, COCs, C5-specialties covering market dynamics, price and profitability forecasts, process technology, market entry strategy, site-specific implementation plans, derivative technology and manufacturing cost.

- **Piperylene sourcing strategy** – for a world leader in hydrocarbon resin production seeking to expand the production of C5, C5-C9 resins, a detailed analysis of the global C5 business covering market dynamics, technology, pricing and profitability, etc. Key to the client's needs was a global analysis of raw C5 production from the global olefins base, taking into account cracker feed slate and extraction/separation technologies.
- **Technology appraisal and the due diligence of a planned C5 operation in China**– for a world leader in hydrocarbon resin production an examination of the technology and manufacturing cost for C5s at a location in China to aid the company's decision as to whether to invest in the project or not.
- **Commercial and technical due diligence of a leading SBC producer**– For a Private Equity firm, carried out the due diligence of a global SBC business, covering production technology, technical audit, asset valuation, business strategy, market dynamics, business financials, etc.
- **DCPD sourcing strategy** – for a world leader in cyclic olefin copolymer production seeking to expand production a detailed analysis of the global C5 business covering market dynamics, technology, pricing and profitability, etc. Key to the client's DCPD needs was a global analysis of raw C5 production from the global olefins base, taking into account cracker feed slate and extraction/separation technologies.
- **Piperylene market study**– for a potential producer of synthetic piperylene, a global review of piperylene market dynamics covering market dynamics, manufacturing cost, pricing and quality requirements.
- **Green isoprene evaluation**– for a leading biotechnology company an independent analysis of green isoprene production together with a comparison of other isoprene technologies based on C5 extraction, isobutylene carboxylation and acetone acetylation. The analysis was focused on technology and manufacturing cost.

Raymond Will – Director, Chemical Consulting

Ray serves as Director of IHS Chemical, where he is primarily responsible for conducting business analysis and market research for consulting projects and the Chemical Economics Handbook and Specialty Chemicals Update Programs. Ray specializes in market demand projections, market research, opportunity searches and strategic planning for inorganic and specialty chemicals industries. During his 25 years at SRI/IHS he has led and participated in a variety of specialty and commodity chemicals consulting projects, including Fluorspar, Fluosilicic acid, Hydrofluoric acid, Fluorocarbons, Fluoropolymers, Pigments, Oil Field Chemicals, Hydraulic Fracturing Chemicals, Water Treatment Chemicals, Cellulose Ethers, Specialty Chemicals, Silicones, Water-soluble polymers, Hydrocolloids, Minerals & Inorganic Chemicals, Pesticides, Hazardous Waste Treatment and Disposal, Solvent Recovery.

Mr. Will holds an MBA (Marketing emphasis) from California State University at Hayward, a BS Pest Management, College of Natural Resources from the University of California at Berkeley, and a Hazardous Materials Management Certificate from the University of California, Berkeley (University Extension).

Masa Yoneyama – Director, Chemical Consulting

Masa Yoneyama is a Director with IHS Chemical Consulting currently engaged in market research and business analysis of the chemical industry in Japan as well as other Asian countries. Before joining IHS, he worked for a chemical division in multinational oil company for 18 years in various capacities in Japan, London and Singapore. Mr. Yoneyama holds an M.B.A. from the University of California at Berkeley, and a B.E., Chemical Engineering, Waseda University.

Dr. Richard Charlesworth – Director, Chemical Consulting

Richard serves as Director for IHS Chemical Consulting based in our Dubai Office. He has acquired more than 20 years' experience in the petrochemical industry in all aspects of the business; financial, commercial, operations, research, design and business planning, as well as consultancy. Richard joined IHS (formerly CMAI) in 2009, and has led many projects across different petrochemical streams that have included market studies, feasibility studies, technology selection studies, feedstock sourcing and pricing studies, marketing strategies, logistics reviews, capital estimates and integration assessments. Many projects have included full financial modeling and production cash cost comparisons of facilities. Mr. Charlesworth holds a PhD, Chemical & Process Engineering, University of Newcastle-upon-Tyne (1996), and a MEng, Chemical & Process Engineering, University of Newcastle-upon-Tyne (1993).

Erik Linak – Senior Principal Analyst

Eric as worked for IHS and the predecessor company, SRI Consulting, for over 25 years. He has authored a number of multiclient reports on coatings and associated raw materials, and has served as Program Director of the World Petrochemicals and Chemicals Economics Programs. Prior to joining SRIC, Mr. Linak worked in the powder coatings, chloro-alkali and toner industries. Mr. Linak holds a B.S. in Chemical Engineering from Ohio State University and an MBA from Carnegie-Mellon University.

Emanuel Ormonde – Senior Analyst

Mr. Ormonde is a Senior Analyst for IHS' Chemical Economics Handbook (CEH) Program with close to fifteen years of experience in analyzing the rubber/elastomer markets, among other chemistries. Mr. Ormonde has also analyzed hundreds of chemical companies' and currently participates in single client activities/research. Areas of expertise include the elastomers chain: (styrene-butadiene rubber, polybutadiene rubber, EPDM, butyl rubber, nitrile elastomers, polyisoprene rubber, polychloroprene rubber, SBC elastomers, natural rubber, chlorinated polyethylene resins and elastomers, chlorosulfonated polyethylene elastomers, fluoroelastomers, polysulfide elastomers and thermoplastic polyolefin elastomers). Emanuel is also involved in ABS and SAN, among other styrenic copolymers, isoprene and styrene-butadiene latexes. Mr. Ormonde holds a B.S. in Biological Sciences from California State University.

About IHS Chemical



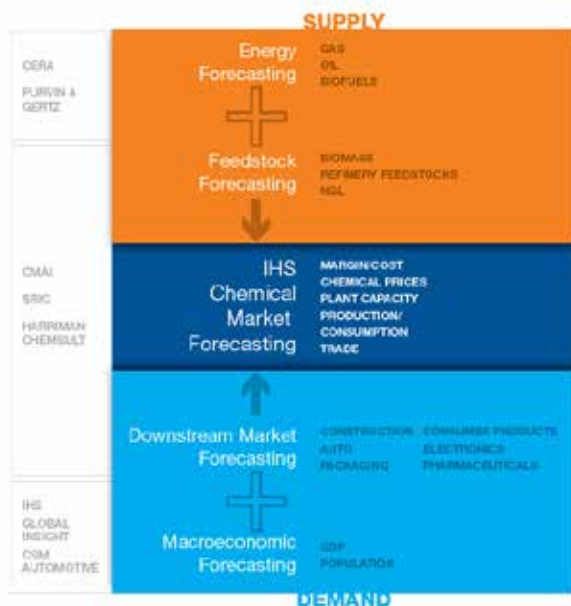
Best-in-Class Brands

IHS Chemical now combines the former CMAI and SRI Consulting groups together with Chemical Week Magazine, Harriman Chemsult, IntelliChem and PCI Acrylonitrile into one integrated business unit comprising its multiclient and single client services. IHS Chemical's experts, analysts and researchers who are well respected throughout the industry for their deep-rooted analysis and forecasts, extends the value that IHS can now offer by connecting clients with the vast resource of insight and expertise that exists across IHS including energy, supply chain and economics.

Comprehensive Coverage

IHS Chemical provides the most comprehensive chemical market content and industry expertise in the world. The company has more than 200 dedicated chemical experts working together to create a consistent and integrated view across more than 300 industrial chemical markets and 2,000 chemical processes for 95 industries. Ensure that your decisions are based on broad, comprehensive information, forecasts, intelligence, and analysis.

IHS has assembled a team of chemical experts that offers an unprecedented coverage level for core chemical markets and technologies. Backing them is a larger IHS community of experts covering related markets, from energy and the macro economy to the world's largest chemical-using industries, such as automotive, construction and others. IHS Chemical's intellectual capital is built on an operating model that utilizes over 1,800 consultants, researchers and economists to advance cross-disciplinary collaboration and analysis.



About IHS

IHS is the leading source of information, insight and analytics in critical areas that shape today's business landscape. Businesses and governments in more than 165 countries around the globe rely on the comprehensive content, expert independent analysis and flexible delivery methods of IHS to make high-impact decisions and develop strategies with speed and confidence.

IHS has been in business since 1959 and became a publicly traded company on the New York Stock Exchange in 2005. Headquartered in Englewood, Colorado, USA, IHS is committed to sustainable, profitable growth and employs more than 8,000 people in 31 countries speaking 50 languages around the world.

IHS serves businesses and all levels of governments worldwide ranging from 85% of Global Fortune 500 to small businesses. IHS provides comprehensive content, software and expert analysis and forecasts to more customers in more than 180 countries worldwide.



Information, analytics, and expertise

IHS offers must-have business information, advanced research and analytics, and deep expertise in core industry sectors, such as energy and natural resources, chemicals, electronics, and transportation. We focus on business-critical workflows that support our customers' needs, including:

- Strategy Planning & Analysis: Strategic Planning, Corporate Development, M&A, Investment Analysis, Risk Assessment
- Energy Technical: Exploration-Production, Geoscience, Engineering, Commercial Development
- Product Design: Engineering Design, Research and Development
- Supply Chain: Procurement, Logistics, Operations, Manufacturing
- Environmental Health, Safety & Sustainability: Sustainability, Regulatory, Environment Health and Safety

This interconnected information, expertise, and analytics across industries and workflows allows IHS to provide best-in-class solutions that power growth and value for our customers.

Contact Information

To make an inquiry about this study, please reach out to the IHS Chemical Special Reports team at ChemicalSpecialReports@ihs.com.

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