

**THE POLYESTER/PET VALUE CHAIN: PROCESS TECHNOLOGY
IMPROVEMENTS FROM BTX TO XYLENES AND PTA/DMT
TO RESINS/FIBERS, 2016-2025**

MULTI-CLIENT STUDY PROPOSAL

May 2016



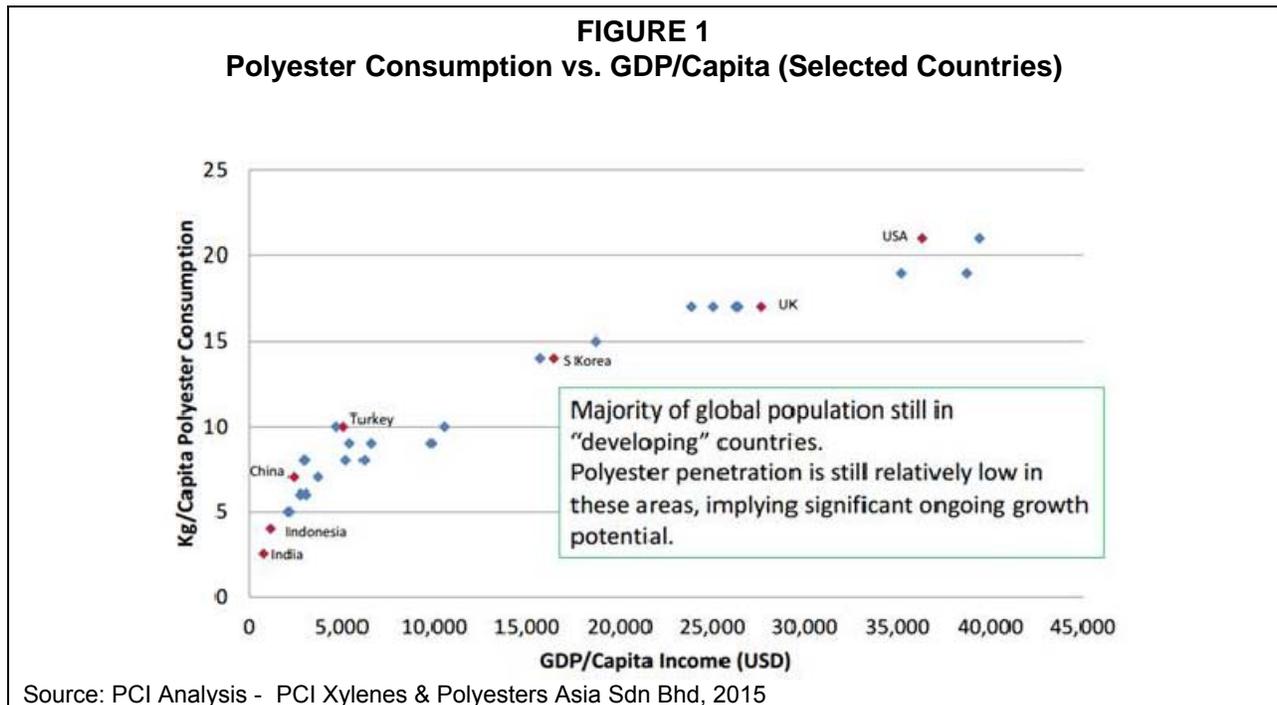
THE POLYESTER/PET VALUE CHAIN: PROCESS TECHNOLOGY IMPROVEMENTS FROM BTX TO XYLENES AND PTA/DMT TO RESINS/FIBERS, 2016-2025

I. ABSTRACT

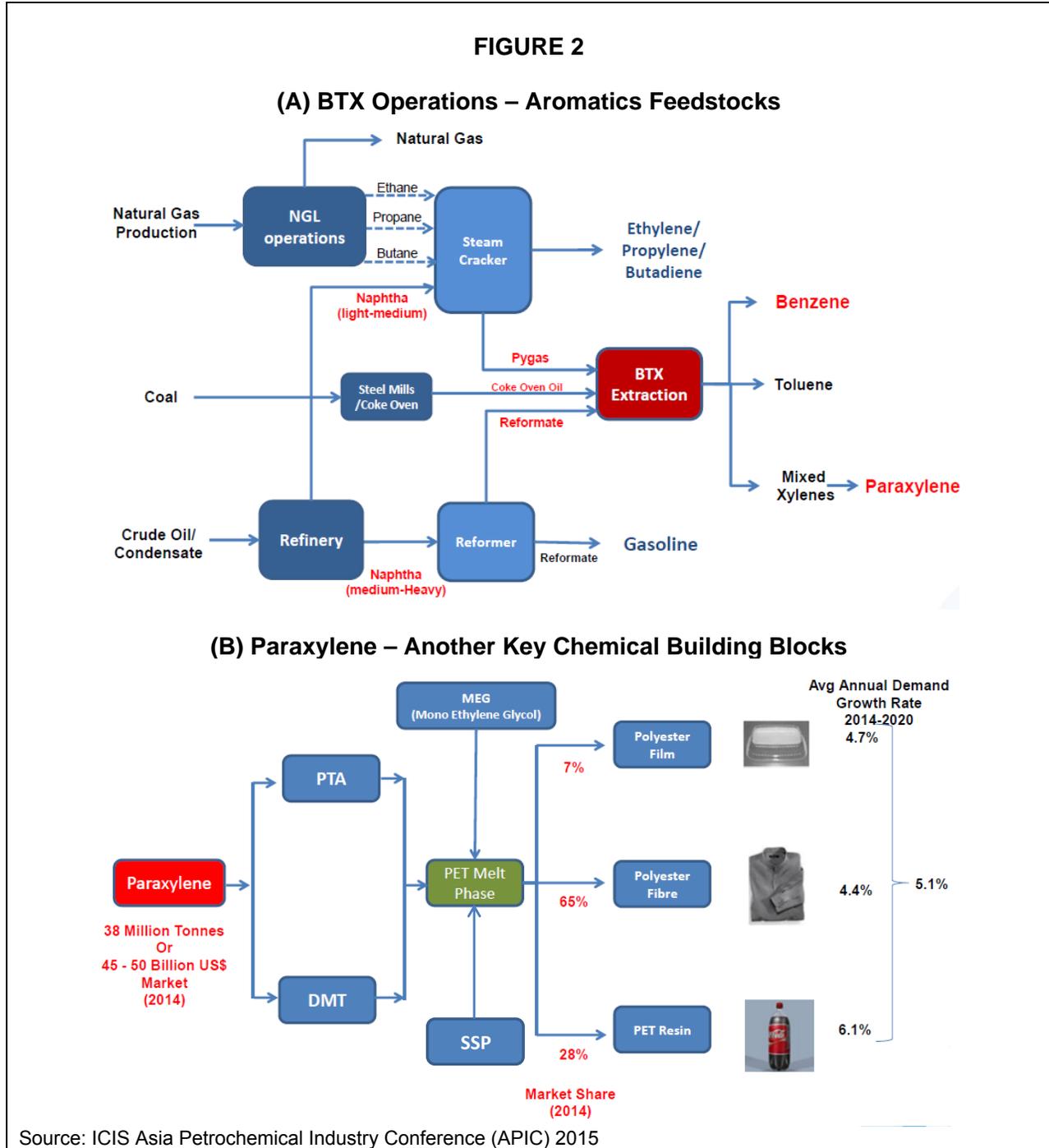
The purpose of this multi-client study is to examine and document new process technologies and practices that will improve the profitability within the petrochemical PET value chain 2015-2025. Influences such as improved BTX separations, methylation of toluene and benzene, new bioaromatics, direct routes to MEG, bioglycols from glycerin, and direct EO from ethane will all be examined, as well as the energy and GHG integration improvements from feedstocks to PET products in one train. It is clear that there is considerable room for improved economics.

II. BACKGROUND

Current forecasts place the growth rate of the global polyester market from 5-6% CAGR between 2015 to 2025. Production/consumption will rise from about 50 MIL mt/yr to almost 110 MIL mt/yr. More importantly, PET growth is driven by rising living standards, urbanization and the retail sector, especially in Asia/Middle East/Africa, where innovative packaging in food and non-food applications, like water, form a direct correlation to developing countries' GDPs. Growth segments like filament variants, food film, medical and others are expected to lead new applications.



As depicted in Figure 2, the production value chain to produce polyesters is one of the most complex and therefore challenging of all the large volume thermoplastics in the global market today. The numerous steps range from producing BTX to p-xylene to PTA with EO to MEG and other complex variants into polyester fibers, resins/packages and specialties.



While there are numerous market studies which examine market supply/demand for PET, p-xylene and MEG, few tend to look into where the most value can be created for the producer, licensor or participant. **The purpose of this multi-client study is to examine and document new process technologies and practices that will shape the future profitability of the new products and process developments during the next ten years to the PET value chain and within the industry, 2015 to 2025. This includes the influences of new feedstocks like bioaromatics, direct routes to MEG, bioglycols from glycerin, direct EO routes from ethane and other developments that can significantly alter competitive dynamics in both the short-term (<5 years) and long-term (10 years).**

If you examine industry trends and the press, you could easily be forgiven if you concluded that bio-PET polyester is taking over the polyester industry! However, today based on the latest news (Ref 2: “The Race to 100% Bio PET” <https://plasticsengineeringblog.com/2012/08/13/the-race-to-100-bio-pet/>) one has to conclude that the 30% Bio PET market based on Bio-MEG capacities of 600,000 mt/yr at Indian Glycols Ltd (India); GreenCol (Taiwan) and BioRenewables means only about 3 MIL mt/yr of Bio-PET is consumed, as compared to 60 MIL mt/yr PET for the entire industry or 5% of the total market.

A more recent Coca-Cola press release highlights the following progress:

Driving Change: Coke and Ford Take Plant Bottle Technology Beyond Packaging...

Since 2012, Coca-Cola has been sponsoring the development of bio-based PET which now accounts for 30% of its North American packaging and 7% globally, for cola’s and Dasani water bottles. Moreover, it has licensed/partnered with Heinz on ketchup bottles and with Ford Motor Company for polyester fabric interiors for its Fusion brand, and plastic cups at Universal Studios. The company has also invested in Virent, Gevo and Avantium to develop bio-PET feedstocks with the aim of substitution at cost competitive production. Noting this trend, other large packaging companies including P&G, Unilever and Georgia-Pacific are evaluating their future packaging choices. Market forecasts suggest the bioaromatics market is expected to reach \$3BIL/yr by 2020.

This driver is highlighted because it shows investment proceeding as a “green choice” and not based on the initial costs, so the argument of biopolymer vs. petrochemical-based on the same costs does not apply in this instance. This is an unusual but noteworthy point for evaluation!

However, for traditional petrochemical industry participants, it is for this reason we stress that the majority (75%) of this study will be focused on improvements to the petrochemical value chain because there are considerable advantages in the existing production and new products chain to be realized.

Specific examples along these lines include: (to be expanded based on “charter” subscriber inputs):

- **To Aromatics, BTX, BTX to P-Xylene**
 1. New processes to remove EB from the feed, either by solvent extraction (GTC Technologies) or from higher conversion with a catalyst
 2. Lower C₈ ring loss in xylene Isom units, because with recycle this can add up to 4-6% of feed
 3. On SMB, single adsorbent vessels (IFP/Axens) and improved pump-around control systems and pumps
 4. New sources of C₈ aromatics e.g. methylation of toluene and benzene
 5. Higher conversion in TDP and ADP units (ExxonMobil)

- **P-Xylene to PTA and Variants**
 6. Variants to create new products (Eastman, Indorama, Mitsubishi)
 7. Purity of feedstocks
 8. Integrated solutions (Mitsubishi, Indesca)

- **Glycols**
 1. Omega (Shell/Mitsubishi) process improvements since 2008-2010
 2. S2G/Pennakem LLC “sugar-to-glycol”
 3. “Bioethanol-to-glycol” as supported by Coca-Cola and practiced by India Glycols Ltd, Greencol, Taiwan; Far Eastern, Taiwan; and others

- **PET Polymerization**
 1. New Titanate Catalysts; New Single-Site developments (Mitsui, Catalyst Technologies)
 2. Better Integration (Mitsubishi, Reliance)

III. THE NEED FOR THE STUDY

As demonstrated in the background examples, there are numerous different developments being undertaken by different companies along the PET value chain by licensors, catalyst developers and producers. The benefits of aggregating these into a single study creates a huge opportunity to extract and determine which combinations (i.e. the best of the best) of pathways, and provides considerable value to producers. For licensors and developers, this in turn creates focus for engineering and R&D to reduce costs and focus on process and product sales value.

Naturally an aromatics complex, is a combination of processing units used to convert naphtha and pygas into the intermediates: benzene, toluene and xylene (BTX). In addition, it can be configured in many different ways depending on the desired product slate, available feedstocks and process investments. This versatility (see Figure 2) means a large amount of optimization. Toluene (the least desired) is always in excess; hence toluene disproportionation and transalkylation are used. The desired product for PET is p-xylene, thus maximizing throughput

via isomerization, recycle and separation means this loop adds to both the complexity but also room for profit improvement.

While the industry has certainly turned to production scale to reduce costs, now 1+ MIL tpy per train, the amount of energy consumed in these conversions and separations is very large, as well the CO₂ emissions are significant. Therefore anything that can optimize these can provide considerable savings to any producer. Addressing factors such as processing severity, LHSV, feedstock splitting, better integration and concentration of products processed can (when combined) offer significant advantages.

For those that understand and appreciate this study undertaking, you will know how important and timely this evaluation is! With energy/production costs playing a critical role in competitiveness and product performance differentiation defining market shares between the players, it is as important as ever to obtain industry benchmarking. Thus TCGR's study – a technical and commercial assessment- is warranted.

Recent multi-client reports and limited-client reports include:

- ***Membranes in Separations: Commercial Advances in Refinery, Petrochemical/ Chemical and Industrial Gases Applications*** (proposed April 2016)
- ***The Intelligence Report: Business Shifts in the Global Catalytic Process Industries, 2015-2021*** (May 2016)
- ***The Middle-East Catalyst Market: Technologies, Applications and Opportunities*** (March 2016)
- ***The Asia-Pacific Catalyst Industry: Markets, Technologies and Manufacturers*** (September 2015)
- ***The Intelligence Report: Business Shifts in the Global Catalytic Process Industries, 2013-2019*** (May 2014)
- ***Specialty Zeolites in Catalysis, 2002-2020: International, Commercial and Technical Progress – A New Era!*** (March 2014)
- ***The Catalytic Process Industries in China: Markets, Technologies & Strategic Implications*** (4 part Series – 2013)
- ***The Industrial Adsorbents Business: Commercial Strategy, Technical and R&D Assessment in Refining, Chemicals/Syngas, Natural Gas and Industrial Gases*** (July 2013)
- ***FCC Additives: Meeting Refiners' Environmental, Performance & Product Slate Flexibility Requirements 2013-2018*** (June 2013)
- ***Unconventional Catalytic Olefins Production: Commercial Vision and Breakout?*** (January 2013)

IV. SCOPE AND METHODOLOGY

As it does in each of its industrially-focused multi-client studies, TCGR will seek the input from “charter” subscribers to help shape the report's final scope/ToC so that it covers and

emphasizes the most pertinent content due the large volume of research and the numerous areas along the value chain (BTX, Glycols, PTA/DMT, PET/PBT variants) that might be of interest.

TCGR's study will document and assess, on both scientific and techno-economic bases, recent developments in the PET value chain from feedstock through to finished products, with the objective of providing insightful, timely advice in R&D/technical, commercial and investment directions.

Section III. The Commercial Landscape will highlight the industry players, Producers, Licensors (Processes) and Suppliers. The state-of the business/industry will be documented, along with the understanding of relationships and interplay between the producers and suppliers. Profiles by company and SWOTs will be used to show differentiation.

Section IV, is the heart of this study, providing technical, techno-economic and commercial benchmarking along the value chain, as shown in Figure 2. Key areas for improvements, the likely commercial timing, availability and the competitive impacts will be measured.

Section V. Polyester Product Developments and Directions - documents new resin, fiber and packaging developments in the pipeline, and how these compare to existing and competitive alternative offerings from a cost/performance perspective.

Section VI is the analysis of **Sections III and IV** brought together to highlight competitive threats/opportunities from a commercial viewpoint from different perspectives. **Section VII,** wraps up the analysis with some decided recommendations and conclusions. TCGR is noted for its sound strategic advice in nearly 35 years of experience.

TCGR's unique background and established global Dialog Group® ensures expert capability and skill level in this study area. TCGR will utilize numerous deeply experienced experts in membranes and separations to assist us to provide insights beyond what other sources that do not have the reach and industrial experience can provide.

For details on the breadth and depth of coverage, the proposed Table of Contents for the study appears on the following page.

Preliminary Table of Contents:

**THE POLYESTER/PET VALUE CHAIN: PROCESS TECHNOLOGY IMPROVEMENTS
FROM BTX TO XYLENES AND PTA/DMT TO RESINS/FIBERS, 2016-2025**

I. Background/Introduction

- A. Background/Need
- B. Scope and Methodology
- C. Contributors

II. Executive Summary

III. Commercial Landscape: Producers, Licensors, Processes and Suppliers

Profiles, SWOTs and understanding the relationships and interplay between the players.

IV. Value Chain Feedstocks, Intermediates and Improvements

A. Sources of BTX

- 1. State of Art
- 2. New Developments (new methanol alkylation technologies, better adsorbents e.g. ADS-47, splitting feeds, etc.)
- 3. Biofeedstocks

B. P-Xylene

- 1. State of Art
- 2. New Developments (more selective extraction, advanced BP crystallization separation)
- 3. Bioaromatics (biomass zeolite oligomerization by Anellotech and BioBTX via pyrolysis are being piloted)

C. PTA Production/Purification

- 1. State of Art
- 2. New Developments (Mitsubishi has developed a more integrated PTA process)

D. Glycols

- 1. State of Art
- 2. New Developments
- 3. Bioglycols (new routes via sugars are being explored, along with glycerol routes to EO, MEG)

E. PET Polymerization

- 1. State of Art
- 2. New Developments (new Ti-based catalysts by Catalytic Technologies Ltd and Melt-Phase “2R” advances by Inventa Fischer are reducing production costs)
- 3. Bio-PET

V. Polyester Product Developments and Directions

- A. New Product Developments (resins, fibers, packaging)
- B. Cost-Performance Comparisons

VI. Competition, Barriers-to-Entry and Commercial Strategies

- A. Threats and Opportunities
- B. Analysis from Different Perspectives

VII. Conclusions and Recommendations

**Charter subscribers (those who sign up for the study before June 30, 2016) will have the opportunity to work with TCGR to refine the scope of the report by delineating areas of particular interest for inclusion in the assessment.*

V. QUALIFICATIONS

The Catalyst Group Resources, a member of The Catalyst Group, works with clients to develop sustainable competitive advantage in technology-driven industries such as chemicals, refining, petrochemicals, polymers, specialty/fine chemicals, biotechnology, pharmaceuticals, and environmental protection. We provide concrete proven solutions based on our understanding of how technology impacts business.

Using our in-depth knowledge of molecular structures, process systems, and commercial applications, we offer a unique combination of business solutions and technology skills through a range of client-focused services. Often working as a member of our clients' planning teams, we combine our knowledge of cutting-edge technology with commercial expertise to:

- Define the business and commercial impacts of leading-edge technologies
- Develop technology strategies that support business objectives.
- Assess technology options through strategy development, including:
 - Independent appraisals and valuations of technology/potential
 - Acquisition consulting, planning and due diligence
- Provide leading-edge financial methodology for shareholder value creation
- Lead and/or manage client-sponsored R&D programs targeted through our opportunity identification process.
- Provide leading information and knowledge through:
 - World-class seminars, conferences and courses
 - Timely technical publications

The client-confidential assignments conducted by The Catalyst Group include projects in:

- Reinventing R&D pipelines
- Technology alliances
- Technology acquisition
- Market strategy

We have built our consulting practice on long-term client relationships, dedication, and integrity. Our philosophy is clear and focused:

***We Provide the "Catalysts" for Business Growth by Linking Technology
and Leading-Edge Business Practices to Market Opportunities***

VI. DELIVERABLES AND PRICING

This report is timely and strategically important to those industry participants and observers both monitoring and investing in the Aromatics Value Chain, and TCGR’s report, based on technology evaluations, market assessments and interviews with key players will assess results and provide opinions beyond the public domain information. As a result, subscribers are requested to complete and sign the “Order Form and Secrecy Agreement” on the following page.

The study, “*The Polyester/PET Value Chain: Process Technology Improvements from BTX to Xylenes and PTA/DMT to Resins/Fibers, 2016-2025*” is expected to be available in October, 2016.

<u>Participation</u>	<u>Deadline</u>	<u>Price</u>
<u>“Charter” Subscribers</u>	<u>before June 30, 2016</u>	\$19,500
The Polyester/PET Value Chain: Process Technology Improvements from BTX to Xylenes and PTA/DMT to Resins/Fibers, 2016-2025		
<u>Post-launch Subscribers</u>	<u>after June 30, 2016</u>	\$21,500
The Polyester/PET Value Chain: Process Technology Improvements from BTX to Xylenes and PTA/DMT to Resins/Fibers, 2016-2025		
Report in PDF format, in addition to subscription price		\$1,000

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ORDER FORM AND SECRECY AGREEMENT

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Please enter our order for **The Polyester/PET Value Chain: Process Technology Improvements from BTX to Xylenes and PTA/DMT to Resins/Fibers, 2016-2025** to be completed in October, 2016, as follows:

_____ **The Polyester/ PET Value Chain: Process Technology Improvements from BTX to Xylenes and PTA/DMT to Resins/Fibers, 2016-2025** for \$19,500 (\$21,500 after June 30, 2016 - post-launch)

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