Aromatics Are Fundamental To The Petrochemical Value Chain

Toluene Conversion Technologies:
- Hydrodealkylation (HDA)
- Disproportionation (TDP)
- Transalkylation (TTA)
- Selective Disproportionation (STDP)

Benzene
- Ethylbenzene/Styrene
- Cumene/Phenol
- Cyclohexane
- Nitrobenzene
- Others

Paraxylene
- PTA/DMT
- Polyester/PET
- Plasticizers

Orthoxylene
- Phthalic Anhydride
- Isophthalic Acid

Metaxylene
- Others

Mixed Xylenes

Toluene

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Benzene – A Building Block & By-Product

What Drives Benzene Supply?

- Refinery operations
- Olefins production
- Polyester market
- Basically, not aromatics

- Pygas/Olefins: 40%
- Coke Oven: 4%
- Reformate/Refinery: 36%
- PX: 15%
- HDA: 5%
Benzene
From Steam Crackers
Simplified Flow Diagram For Aromatics

NGL (Natural Gas Liquids)
- Ethane
- Propane
- Butane

Steam Cracker
- Pygas

BTX Extraction
- Benzene
- Toluene
- Mixed Xylenes

Reformer
- Reformate
- $H_2$

Refinery
- Naphtha

Crude Oil

Pipeline Natural Gas

Gasoline

Crude Oil

Ethylene
Simplified Flow Diagram For Benzene

- **Natural Gas**
  - NGL (Ethane, Propane, Butane)
  - Steamer Cracker (Pygas, H₂)
  - Reformate (Naphtha)
  - Gasoline (Benzene, Toluene, Mixed Xylenes)

- **Pipeline Natural Gas**
  - Ethylene

- **Crude Oil**
  - Refinery (Butane, NGL)

- **Reformer** (BTX Extraction, Reformate, H₂)
Lighter Cracker Feedslates Reduce Benzene Production

Benzene Produced Per Ton of Ethylene

- Ethane
- Propane
- Butane
- Light Naphtha
- Heavy Naphtha
- Gasoil

Cracker Feedstocks

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Benzene
From Refiners
Simplified Aromatics Overview

Natural Gas → NGL

NGL → Ethane Propane Butane

Steam Cracker → Ethylene

NGL → Pygas

Pipeline Natural Gas

BTX Extraction

Ethylene

Benzene

Toluene

Mixed Xylenes

Ethylene

Reformate

H₂

Reformer

Gasoline

Crude Oil

Refinery

Naphtha
Refineries Navigating Through A Challenging Environment

- Start Ups & Capacity Rationalization
- Change In Fuels
  - Environmental
  - Biofuels
- Change In Automobiles
  - Growth In Asia
  - Efficiency Standards
- Advantaged Feedstocks
Over A Decade Of Production Declines Erased

Oil production continues to grow, led by increasing production for Bakken and Eagle Ford.

Shale Development Impact On Aromatics?

• Shale developments have resulted in an increase of crude oil as well as natural gas production.

• The impact on aromatics has mostly been negative, but the reality is complex.
  – Increased shale oil production has reduced the production of aromatics, thereby reducing supply and;
  – It has resulted in increased demand for blending components, which includes aromatics (excluding benzene), thereby increasing the cost of aromatics but;
  – It has breathed new life into refineries keeping associated aromatics production from shutting down.

• Downstream derivatives are also benefitting from lower costs and energy, so it’s not all bad news.

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Impact Of Gasoline Regulations - MSAT

Air Toxics/MSAT (Bz Limit)
Remove benzene from gasoline
More benzene

Benzene Concentration (Volume %)

- Average Benzene Conc., 2011 Report

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Next Refining Hurdle – Ethanol Blendwall

Renewable Fuels (Ethanol) → Less petroleum gas demand → Less benzene

Renewable Fuel Standard Expansion

Billions of Gallons

- RFS1
- RFS2

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Benzene
From Paraxylene
Simplified Aromatics Overview

- **Natural Gas**
  - NGL
  - Ethane
  - Propane
  - Butane

- **Steam Cracker**
  - Pygas
  - Reformate

- **BTX Extraction**
  - Benzene
  - Toluene
  - Mixed Xylenes

- **Crude Oil**
  - Refinery
  - Naphtha
  - Gasoline

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Polyester Demand Drives Benzene Supply

Global Demand Growth
(2007=1)

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Benzene Supply From Paraxylene

- These units are focused mostly on PX production.

2011

- Pygas 39%
- HDA 4%
- Coke Oven 5%
- Polyester 16%
- Reformate 36%
- TDP 0%
- STDP 5%
- TA 6%
- PXE 5%
- Polyester 16%
- Reformate 36%

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Benzene
From Other Sources
Benzene Supply From Other Sources

- Coke Oven by-product from steel production
- HDA – On purpose from toluene

2011

- Pygas 39%
- HDA 4%
- Coke Oven 5%
- Polyester 16%
- Reformate 36%
- TDP 0%

- STDP 5%
- TA 6%
- PXE 5%
Looking For Another Route For Benzene

Coal

LPG

BZ

CH₃OH

Other
Coal To Benzene

BENZENE
Benzene Content in Feedstreams

Composition (Weight %)

Pygas
Reformate
Coke Oven Light Oil

Benzene
Toluene
Mixed Xylenes
Total Aromatics

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Benzene Capacity Expansions

Million Metric Tons

-1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5


Americas
Europe
Middle East/Africa
Asia
Hypothetical
Average Demand

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Benzene
Price Forecast
Historical Benzene Prices

Price (Cents Per Gallon)

- $6.00
- $5.00
- $4.00
- $3.00
- $2.00
- $1.00
- $0.00

Jan-2000, Jan-2002, Jan-2004, Jan-2006, Jan-2008, Jan-2010, Jan-2012, Jan-2014

US | Asia

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Spot Benzene Prices Are Flat
(U.S. Gulf Coast Benzene Rolling Daily Spot Posting)

The posting of the current month rolls forward on the 25th calendar day (or next business day thereafter)
Benzene Derivatives
Benzene Derivatives Benefit from Shale Advantaged Feedstocks

Benzene

- EB/Styrene 51%
- Ethylene
- Cumene/Phenol 20%
- Propylene
- Cyclohexane 11%
- Hydrogen

Polystyrene
- EPS
- ABS, SBR, UPR

Bisphenol A → Polycarbonate

Phenolic Resins

Caprolactam → Nylon 6

Adipic Acid → Nylon 6,6
Benzene – Styrene – Polystyrene
In Intermediate Hell

What it feels like to be styrene
Styrene Flow Diagram

- Ethylene (0.3)
- Benzene (0.8)
- Propylene

Diagram:
- Ethylene (EB) interconnected with Benzene (1.07) and Propylene (PO/SM)
- EB connects to SM
- SM connects to PS, EPS, ABS, and PO

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Styrene Flow Diagram

Ethylene (0.3)

Benzene (0.8)

Propylene

PO/SM

EB (1.07)

SM

PS
EPS
ABS

PO
Styrene Capacity Expansions Slow

Million Metric Tons


Americas
Europe
Middle East/Africa
Asia

Oversupply in 2010
Styrene Capacity Expansions Slow
Expansions Slow
Shutdowns Offsetting Capacity Additions
Styrene Capacity Moves East

2002

56%

44%

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Styrene Capacity Moves East

2017

37%

63%
Can imports of benzene continue to grow to support export oriented derivatives?

Yes, as long as the raw material and energy advantage offsets the benzene and shipping disadvantage.
The Outlook For Benzene & Styrene

- Benzene prices have retreated from historic highs. Lower energy prices will allow benzene prices to decline although the relationship of benzene relative to energy will remain strong.
- Long term global styrene balance is forecasting an improvement in operating rates.
- Styrene exports will continue to be strong from North America and will hold up spot styrene prices.