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Advanced Technology in Aromatics
Reducing Investment and Operating Cost

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Para-xylene Demand: World-Wide

- Para-xylene ($pX$): High value, transportable chemical produced from heavy naphtha; used in polyester fiber & PET resin
- Demand growth 5% WW exceeds GDP
- China consumes more than half of all $pX$ produced and imports more than half of what it consumes
- Even with large China build, new capacity cannot keep up with demand
  - 2018 China imports: 16.2 MMTA
  - 2028 China imports: 12.6 MMTA
- $pX$-naphtha spread $400-450 /Ton, can exceed $600
- Break-even w/ modern technology now < $200 /Ton

Regional $pX$-Naphtha Spread  $/MT

China $pX$ Supply Demand Balance

World $pX$ Supply Demand Balance

Strong Fundamentals: $pX$ is Cheaper to Produce than Buy
India pX Value Chain – Capacity and Demand Growth

- India currently [’17] net exporter of pX. Mainly to China & SE Asia country
- Due to fast growing demand by 2023 India will be in deficit of pX

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Source: PCI Q2 2018, HIS * - ’14-’19 CAGR%
Adding New \( pX \) Capacity in India

- **Domestic demand**: Fast growing domestic \( pX \) & derivative demand
- **Slow supply increase**: Capacity expansion slower than demand
- **Feed stock availability**: India’s exported ~ 200 kb/d naphtha in 2018 – Forecasted exports ~ 150 kb/d by 2025
- **Location**: India’s major export goes to China & SE Asia. So proximity to Asian consumers is a great advantage for India exporters
UOP’s Modern $pX$ Technology (2018)

**Step change in energy efficiency**
- The Energy Efficient Aromatics Complex (EEAC) reduces energy consumption 25-40%.
- Advanced heat integration.
- 8 licenses since 2010.
- **3 commercial operations since 2014**

**Game-changing LD Parex technology**
- Reduces $pX$ complex capital cost by 20%.
- Builds on EEAC and achieves **20% further energy savings**.
- 13 new LD Parex plants licensed since 2016.

**New economies of scale**
- ADS-47 adsorbent provides 25% higher capacity.
- Proven in 18 commercial applications since 2011.
- UOP adsorbent chamber and rotary valve designs help provide unmatched reliability at capacity exceeding **2 MMTA $pX$ in a single train**

**Improved feed utilization**
- Latest generation CCR Platforming, Isomar, and Tatoray catalysts can deliver **substantial economic benefit** through improved yields, higher stability, and higher activity.
Innovation Drives Value Creation

UOP I-500 Isomar™ EB Dealk Catalyst
• Low xylene losses / 11 commercial applications

UOP Tatoray™ PTD Process
• High Yield / 1 operating unit

Energy Efficient Aromatics Complex
• 25-40% lower energy consumption
• 3 operating units

UOP TA-30 Tatoray Catalyst
• Max conversion of heavy aromatics
• 9 operating units

UOP ADS-47 Parex™ Adsorbent
• 25% higher capacity
• 18 commercial applications

Upgraded Catalysts
• UOP R-334 Platforming Catalyst
  – Increased aromatics, \(H_2\) & \(C_5^+\) yields
  – 6 operating units
• UOP I-600 EB Isom Isomar Catalyst
  – 2 operating unit

UOP R-284 Platforming™ Catalyst
• Improved aromatics yields
• 4 operating unit

LD Parex Aromatics Complex Relaunch
– 20% CapEx reduction
– 20% lower energy than EEAC
– ADS-50 adsorbent
– 13 complexes in D/C, 20+ MMTA total capacity licensed

Toluene Methylolation
- 15-25% CapEx savings
- 20-35% lower utilities
- 20-40% less naphtha for same pX capacity

UOP ADS-43 MX Sorbex Adsorbent
1st start-up of Modern LD Parex

UOP’s Hallmark: Continuous Value Creation & Commercialization
## Technology Adoption Since 2010

<table>
<thead>
<tr>
<th>Description</th>
<th>Innovation</th>
<th>Year Introduced</th>
<th>Commercial Applications by 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS-47 Parex Adsorbent</td>
<td>25% higher capacity</td>
<td>2011</td>
<td>18</td>
</tr>
<tr>
<td>I-500 EB-dealkylation</td>
<td>Higher xylene retention, activity and benzene purity</td>
<td>2013</td>
<td>11</td>
</tr>
<tr>
<td>Isomar Catalyst</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA-32 (30) Tatoray Catalyst</td>
<td>Higher xylene selectivity and heavy feed processing</td>
<td>2014 (2010)</td>
<td>10 (9)</td>
</tr>
<tr>
<td>EEAC Energy Efficient</td>
<td>25% less energy consumption for PX from reformate</td>
<td>2010</td>
<td>8</td>
</tr>
<tr>
<td>Aromatics Complex Flowscheme</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD Parex Light Desorbent</td>
<td>20% less CAPEX and 40% less energy consumption</td>
<td>2015</td>
<td>13</td>
</tr>
<tr>
<td>Parex Flowscheme</td>
<td></td>
<td></td>
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</tbody>
</table>

- Rapid adoption of breakthrough technologies since 2010
- UOP capabilities are the keys to success:
  - Continuous investment in state-of-art R&D to **invent**
  - Leading engineering, manufacturing and service to **commercialize and execute**

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Reliable Track Record Delivers Successful Market Adoption
LD Parex: State of the Art

13 world-scale pX Complexes
20+ MMTA total pX capacity licensed to date

Advantages over pDEB and crystallization systems

- Light desorbent dramatically relaxes Parex feed fractionation need, enabling **40% less energy requirement**
- **Greatly simplified flowscheme** eliminates 20% of equipment and CapEx
- **UOP has 40+ years experience with light desorbent** in 16 commercial plants
- **UOP’s unique rotary valve system** is unmatched in simplicity and reliability

Enabled by UOP adsorbent capability

- ADS-50 based on ADS-47 adsorbent technology
- ADS-47 commercialized in 2011 with **25% higher capacity** vs previous generation
- **ADS-47 reliability proven** in 18 commercial plants
Modern UOP Aromatics Complex: LD Parex

- Uses Light Desorbent (Toluene)
- Desorbent taken as Raffinate Column overhead & Extract Column sidetrain
- $A_9$ limit in XC overhead no longer a design constraint
- Overall complex still evaluated as a “system” to increase heat integration and reduce energy input

20% Less Equipment than Conventional Design
LD Parex Delivers Lowest Cost pX Production

20% CapEx Reduction & 40% Energy Reduction

EEAC
- 3 in operation
- 5 Design/Construction

2010

25% Energy Reduction

Conventional

2009

LD Parex

2018

20% More Energy Reduction

20% CapEx Reduction

40% Energy Reduction

Energy Consumption

CAPEX
Cost Advantage from Continuous Improvement: Reformate-based pX Complex

Reformate to pX, Asia feed, product, & energy prices 2017/8
Reliability and Scale

- World-scale $pX$ plant capacity
  - 1975: 150 KMTA
  - 1995: 400 KMTA
  - 2015: 1,500 KMTA
  - 2018: 3,000+ KMTA

- Increasing economies of scale without sacrificing reliability requires strong licensor capabilities
  - Improved adsorbents and catalysts
  - State-of-art design practices and validation
  - Latest equipment design and fabrication methods

- Complex design is not only $pX$ purification
  - Limitations in any unit or equipment can bottleneck the entire production
  - Lost production from a bottleneck can be very costly for modern plants
    - Example: 1/3 lost capacity of world-scale plant for 2 years costs $120 M

UOP Rotary Valve (RV) and Adsorbent Chamber Internals (ACI)

- Proven >99.9% reliable at all capacities
- Single train capacity reaching 3 MMTA $pX$
- ACI design optimizes flow distribution to maximize adsorbent performance

**Historical Knowledge of Entire $pX$ Complex Key to a Reliable Design**
**LD Parex Case Study**  **Location: Middle East**

- Para-xylene Capacity: 1,400 kMTA
  - National Oil Company
  - Integrated refinery and petrochemicals plant
  - 12 UOP process units for petrochemicals and clean fuels production
- State of the Art Facility, Utilizing Latest Technologies for Competitive Advantages vs. older complexes
  - Optimized solution using LD Parex delivered nearly $2 billion in NPV
- Full Support Project Execution
  - UOP managed entire engineering design
  - Seamless FEED design
  - Faster project execution

### OpEx Impact of LD Parex Conversion

<table>
<thead>
<tr>
<th></th>
<th>Heavy Desorbent</th>
<th>LD Parex</th>
<th>Savings $/MT pX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Base</td>
<td>Base - 12%</td>
<td>5</td>
</tr>
<tr>
<td>Steam</td>
<td>Base</td>
<td>Base - 44%</td>
<td>4</td>
</tr>
<tr>
<td>Electricity</td>
<td>Base</td>
<td>Base - 3%</td>
<td>0.5</td>
</tr>
<tr>
<td>p-DEB</td>
<td>Base</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>10.5</strong></td>
</tr>
</tbody>
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**Tremendous value added by latest generation technology**
PX – Benzene Flexibility with Toluene Methylation

- Selective alkylation of toluene with methanol to generate above-equilibrium \( pX \) xylenes
- Significant decrease in cost of \( pX \)
  - 15-25% CapEx savings
  - 20-35% lower utilities
  - 20-40% less naphtha for same \( pX \) capacity

**Revamp: 10% \( pX \) Yield Benefit with Toluene Methylation**

Existing plants can benefit from toluene methylation.
LD Parex is the latest in a line of UOP innovations, offering regional producers significant cost advantage over pX capacity in East Asia.

The LD Parex design delivers 20% CAPEX savings and 40% less energy and carbon emissions.

UOP has effectively scaled its pX technology, with successful and proven operations:
- >2.5 MMTA single train plants are in D/C
- New designs possible up to 3 MMTA

UOP technology is among the world’s most reliable, with virtually all licensed units operating well, at or above nameplate capacity since start-up.

UOP’s commitment to innovation ensures our customers will be low cost producers for years to come:
- LD Parex – Breakthrough Technology
- ADS-50 Adsorbent
- Toluene methylation
- Future Improvements