Feedstock Challenges and Innovative Routes to Feedstock

6th Indian Oil Petrochemical Conclave – 2017

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Agenda

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Context Setting

Global Petrochemical feedstock scenario & outlook
- Ethylene Feedstock sources & recent developments
- Propylene Feedstock sources & recent developments

Indian Petrochemical feedstock scenario & outlook
- Ethylene Feedstock sources
- Propylene Feedstock sources
- Supply-Demand Gap
- Potential future options for India

Conclusion
Ethylene & Propylene are key building blocks for Petrochemicals

**Global Basic Chemicals Consumption (2016)**

- Ethylene: 38%
- Propylene: 26%
- Benzene: 13%
- Toluene: 7%
- Butadiene: 3%
- Mixed Xylene: 13%

Global Consumption of Basic chemicals in 2016 is estimated at >380 Mn tonnes; Over 60% of which is attributed to Ethylene & Propylene as building blocks for further conversion.

Source: ICIS Supply and Demand Database
Ethylene derivatives & end-uses / applications

- **Polyethylene**: Packaging, Pipes, Cable Insulation
- **EDC**: Construction, Housing Sectors
- **EVA**: Foaming applications, Coating, Packaging, Agriculture Industries
- **VAM**: Paints, Adhesives, Coatings
- **Ethylene Oxide**: Building Insulation, Household Use (for e.g Furniture)
- **EPDM**: Textiles, Packaging, Detergents, Emulsifiers, Polishes, Pharmaceuticals, Corrosion Inhibitors, Seals, tubes, insulations

*Indicates that India is import dependent for the value chain*
Polypropylene derivatives & end-uses / applications

- **Polypropylene**
- **Acrylonitrile**
- **Propylene Oxide**
- **Cumene**
- **Acrylic Acid**
- **Butyraldehyde**

*India is expected to turn net deficit by 2018*

- **Resins (ABS, SAN, ASA)**
- **Rubber (NBR)**
- **Acrylic Fibres**
- **Propylene Glycol**
- **Polyether Polyol**
- **Acetone**
- **Phenol**
- **SAP**
- **Acrylic Acid Esters**
- **Oxo Alcohols**

- Film, Fibres, Appliances, E&E, Automotive, Households, Pipes, Medical, others
- E&E, Appliances, Packaging, Auto, others
- Automotive
- Carpets, Clothing, others
- Antifreeze, Solvents
- Insulation, Furniture, Coatings, others
- Electrical, Architectural, Security, Transportation applications
- Automotive, Aerospace, Electrical, Electronics Sectors
- Diapers, Hygiene, others
- Adhesives, Coatings, Paints
- Plasticizers, Solvents

Indicates that India is import dependent for the value chain
Olefin Feedstock routes – Several options & opportunities for Refinery – Petrochemical integration
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Global Ethylene Supply >>> Steam Cracker Based

▶ >95% of global Ethylene supply to be Steam Cracker based
▶ Increasing supply from non-traditional routes CTO/MTO that are currently restricted to China
▶ MTO/CTO prospects are questionable in a lower oil scenario, from either narrower spread between coal and oil based feedstock or lack of imported MeOH feedstock as US-based MeOH expansions cancelled/delayed in low oil case

Global Ethylene Supply by Production Routes

Source: ICIS Supply and Demand Database
Global Cracker Feedstock Slate is lightening, primarily driven by the shale gas boom in North America…

SOURCE: ICIS Supply & Demand database
Feedstock evolution – regional variations on ethylene supply (Million Tonnes)

**North America**
Feedstock lightening, with increasing ethylene supply from ethane

**Asia**
Naphtha remains the leader, with CTO/MTO gaining share

**Middle East**
Ethane remains the main feedstock

**Europe**
Naphtha remains the main feedstock, though there may be some lightening

Source: ICIS Supply and Demand Database
Global propylene supply sources will have evolved to be more diversified as new routes have emerged

- Steam cracking and FCC propylene remain the dominant sources for propylene production.
- Lightening of cracker feedstock, coupled with strong demand for propylene derivatives & ample availability of propane, has given rise to propylene supply from on-purpose production (through Propane Dehydrogenation - PDH)
- Increasing supply also from non-traditional routes CTO/MTO but are currently restricted to China

Source: ICIS Supply and Demand Database
Regional outlook for propylene supply sources... Significant variations across regions...

**North America**
- On-purpose propylene production from PDH is likely to grow
- 2010, 2015, 2020, 2025 bars show increasing trend

**Middle East**
- Propylene supply source distribution remain largely unchanged
- 2010, 2015, 2020, 2025 bars show modest changes

**Asia**
- Growing supply from non-traditional routes
- PDH/CTO/MTO mostly due to China
- 2010, 2015, 2020, 2025 bars show significant growth, especially in 2020 and 2025

**Europe**
- Steam Cracking remains the majority propylene source
- 2010, 2015, 2020, 2025 bars show stable distribution

Source: ICIS Supply and Demand Database
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India’s ethylene supply is mostly steam cracker based, with a fairly mixed cracker feedstock slate

Around 98% of Ethylene supply in India is Steam Cracker based

With the start up of several mixed feed crackers in 2016-2017, the feedstock slate has shifted slightly towards more ethane feed. As of 2017, Ethane in particular accounts for 44% of the feedstock slate in 2017, almost on par with naphtha.
India could see greater integration between refining and petrochemical as companies plans to add crackers to their existing refinery complexes.

**RELIANCE (HAZIRA)**
Naphtha; LPG; Ethane 930kta

**RELIANCE (VADADORA)**
Naphtha 180kta

**IOCL (PANIPAT)**
Naphtha 800kta

**HALDIA (HALDIA)**
Naphtha 670kta

**OPAL (DAHEJ)**
Naphtha; Ethane; LPG 1100kta

**IOCL (PARADEEP)**
Naphtha/Mixed 1000kta potentially 2020 start-up

**HMEL (PHULO KHARI)**
Naphtha/Mixed 1200kta potentially 2025 start-up

*Integrated refinery and petchem complex

*“Integrated” with Jamnagar Refineries

Source: ICIS Supply and Demand Database
Various models exist in India in managing the cracker feed; Some have expanded their flexibility to enhance optimisation.

- **RELIANCE (JAMNAGAR)**
  - Ethane (off gas)
  - 670kta
  - *Integrated with Jamnagar Refineries*

- **GAIL (PATA)**
  - Ethane
  - 450kta
  - Ethane; LPG
  - 530kta
  - *In-situ ethane*

- **RELIANCE (HAZIRA)**
  - Naphtha; LPG; Ethane
  - 930kta

- **RELANCE (NAGOTHANE)**
  - Ethane; LPG
  - 450kta
  - *Ethane is imported from the US and received at the Dahej terminal and distributed to feed the 3 crackers*

- **OPAL (DAHEJ)**
  - Naphtha; Ethane; LPG
  - 1100kta
  - *Ethane comes from imported rich LNG*

- **BCPL (ASSAM)**
  - Ethane; LPG; Naphtha
  - 220kta

- **RELIANCE (DAHEJ)**
  - Ethane; LPG
  - 365kta

Source: ICIS Supply and Demand Database
All of India’s propylene supply comes from traditional routes i.e. Steam Cracking and FCC

- More than 60% of propylene supply comes from FCC
- There has been no announcement of investments in alternative production routes in India, although there has been some interest
- Over the longer term, with growing downstream demand for propylene based derivatives, ICIS forecasts development of on-purpose propylene production via PDH in the country

![India Propylene Supply by Production Routes](Image)

Source: ICIS Supply and Demand Database
Propylene from FCC – Good example of Refinery-Petrochemical integration; Many refiners are already maximizing their operations by integrating with propylene and its derivatives.

- **IOCL (PANIPAT)**: 175kta
- **HMEL (PHULO KHARI)**: 400kta
- **RELIANCE (JAMNAGAR)**: 1000kta/450kta/450kta
- **BPCL (MUMBAI)**: 33kta
- **MRPL (MANGALORE)**: 440kta
- **CHENNAI PETROLEUM (MANALI)**: 80kta
- **IOCL (MATHURA)**: 20kta/165kta
- **IOCL (PARADEEP)**: 700kta potentially 2020 start-up
- **ESSAR (VADINAR)**: 250kta potentially 2020 start-up
- **BPCL (KOCHI)**: 500kta potentially 2020 start-up
- **HPCL (VIZAG)**: 74kta
- **HPCL (VIZAG)**: 320kta potentially 2021 start-up

*FCC unit started up. Propylene production expected in 2018*

Source: ICIS Supply and Demand Database
Indian Olefin Supply-Demand Gap…Expected to further widen

With very limited investments planned, India is expected to see a growing deficit of olefins derivatives.

By 2020, India’s deficit of ethylene and propylene derivatives is expected to reach 2.3 million tonnes ethylene equivalence and 1.1 million tonnes propylene equivalence respectively.

The deficit is expected to at least triple by 2025 if no further investments are made.
Indian Olefin Supply-Demand Gap…Expected to further widen
With very limited investments planned, India is expected to see a growing deficit of olefins derivatives..

Investment OPPORTUNITIES remain untapped...
But what options could India explore to fill this gap?

- Steam Cracking – Naphtha / Mixed feed?
- Propane Dehydrogenation (PDH)?
- Methanol to Olefin (MTO)?
- Coal to Olefin (CTO)?

Could India be more competitive than China for these new business / feedstock models?
India is a net exporter of naphtha, mainly to NE Asia, with US being an important market as well in recent years; Naphtha surplus is concentrated in the West.

- US has become the single largest market for India’s naphtha since 2013.
- Between 2013-2016, India shipped more than 9 million tonnes of naphtha to the US market.
- In 2016, India exported more than 3 million tonnes of naphtha to NE Asia.
  - China, Japan, South Korea and Taiwan have similar share of the volume.
- It is worth noting that Singapore also imported considerable volumes – an annual average of 460kt in the last 5 years.
- Much of India’s exports would have come from West India.
- That said, a shortage of heavy naphtha has appeared in the West with the start-up of the mega PX plant in 2017.

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**India’s Naphtha Supply and Demand**

*Petrochemical sector makes up 96% of naphtha demand in FY2015-16*

- **North**: 2610
- **Northeast**: 191
- **East**: 144
- **South**: 1055
- **West**: 2768

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**India Naphtha Net Exports**

- **2009**: NORTHEAST ASIA: 4000, MIDDLE EAST: -2000
- **2010**: NORTH AMERICA: 2000, NORTH AMERICA: -4000
- **2011**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000
- **2012**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000
- **2013**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000
- **2014**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000
- **2015**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000
- **2016**: SOUTH & SOUTHEAST ASIA: 1000, SOUTH & CENTRAL AMERICA: 1000

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Source: ICIS Supply and Demand Database

Source: MOPNG; ICIS Consulting
In both high and low oil scenarios, an Indian naphtha cracker integrated to PE & PP yields higher margins than a similar cracker in China.

- India’s proximity to major naphtha supplying region Middle East provides an important cost advantage over China.
- Fixed cost is also generally lower in India.
- Furthermore, Polyolefin prices are typically higher in India than in China.

Source: ICIS Consulting
Mixed feed crackers for feedstock flexibility… with volatility around crude, increased flexibility in cracker feed becomes a hedging tool for producers…

- Ethane has a clear cost advantage over naphtha as a cracker feed in a $100/bbl oil world
- However, the cost advantage is reversed when oil prices are low
- That said, given the vast difference in yields between feeds, precise management of derivatives sales will be crucial

*Source: ICIS Consulting*
China has witnessed a spate of on-purpose propylene capacity start-ups based on imported propane.

As much as 4.5mtpa of PDH capacity was added in the last three years, with another 2.3mpta expected by 2020, making up close to 20% of propylene capacity in China.

China PDH units are dependent on propane imports. More than half of the imports is from Middle East, with the US also an important supplier.

In 2016, around 90% of imports to China came from the two regions.

Could India adopt or adapt this business model?

Source: ICIS Supply and Demand Database
In both high and low oil scenarios, an Indian PDH integrated to PP production returns better margins than a PDH in China.

- India's proximity to major propane supplying region Middle East provides an important cost advantage over China.
- Fixed cost is also generally lower in India.
- Furthermore, product prices are higher in India than in the Chinese market.

Source: ICIS Consulting
Similar to PDH development, China witnessed the first wave of CTO/MTO capacity start-ups in the last few years.

- Around 2.3mtpa of CTO/MTO capacity was added in the last three years, with another 2.6mpta expected by 2020, making up close to 20% of ethylene capacity in China.
- While CTO units utilise the vast coal resources China has domestically, most MTO units operate on imported methanol.
  - In 2016, close to 60% methanol imports come from the Middle East.

Could India adopt or adapt this business model?
In both high and low oil scenarios, an Indian MTO unit integrated to PE production is expected to yield higher margins than a similar MTO unit in China.

- India's proximity to major methanol supplying region Middle East provides an important cost advantage over China.
- Fixed cost is also generally lower in India.
- Furthermore, product prices are higher in India than in the Chinese market.

Source: ICIS Consulting
Among Asian producers, India is relatively cost competitive and enjoys better margins than Chinese producers under most feedstock options.
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Conclusion
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- Strong demand fundamentals shall drive future investments in India
  - Refinery-Petrochemical integration will further enhance competitiveness for Indian producers
- Traditional steam cracking shall remain evergreen
  - Mixed feed crackers allow for feedstock flexibility
  - Well diversified business model due to better product mix
  - Competitiveness further enhanced in the Low-oil environment prevailing
  - However, huge CAPEX involved
- Investments into Non-traditional business modes will also be required
  - **PDH based cluster** to facilitate downstream investment into Propylene derivatives
  - **MTO project** based on merchant methanol from Middle east with potential Back-integration to Methanol in Middle east in future
  - **CTO project** based on imported / domestic coal