US Petrochemicals

The growing importance of export markets

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- Plays and Basins
- Costs and Technology
- Companies and Transactions

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- Crude Oil Markets
- Midstream Oil and Natural Gas Liquids
- Refining and Marketing
- Company Strategies and Performance

**POWER, GAS, COAL & RENEWABLES**
- Chemical Week and Market Daily Service
- Base Chemicals & Plastics
- Specialty Chemicals
- Costs & Technology
- Company Benchmarking & Analytics
- Global Gas
- Coal
- Power and Renewables
- Regional Gas, Power and Coal Markets

**ENERGY-WIDE PERSPECTIVES**
- Long-Term Planning & Scenarios
- Climate Strategy
- Curated Content
- Integrated Energy Events & CERAWeek
The Chemical Industry Enables Modern Living

**Chemical industry value chain**

**Customers**
- Transportation
- Consumer products
- Packaging
- Construction
- Recreation
- Industrial
- Medical
- Pharmaceutical
- Personal care
- Textiles
- Electronics
- Aerospace
- Business equipment

**Natural resources**
- Oil
- Gas
- Coal
- Minerals
- Renewables

**Base chemicals**
- Olefins
- Aromatics
- Chlor-alkali
- Others

**Chemical intermediates**
- Commodities
- Differentiated commodities
- Technical specialties

**Formulated products / performance materials**

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Global economic growth remains strong and steady, if serious mistakes on trade, monetary policy, and international relations can be avoided

<table>
<thead>
<tr>
<th>Year</th>
<th>World</th>
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<td>2020</td>
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Source: IHS Markit

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Economic growth in advanced countries and emerging markets are key drivers to petrochemical demand growth.

**GDP Elasticity: rate of market growth / rate of global economic growth**

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Source: IHS Markit © 2018 IHS Markit
Ethylene and propylene remain in high growth mode; methanol growth stabilizes

Global demand growth and 2017 estimated total demand

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<td>Paraxylene</td>
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<td>41</td>
<td>0.9</td>
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Source: IHS Markit
The energy and petrochemical industries are closely related.
There are several primary routes to produce olefins:

- **Crude Oil**
  - Crude Unit
  - FCC Unit
  - LPG, Naphtha, Gas Oil

- **Natural Gas**
  - Nat Gas Processing
  - Ethane, Propane, Butane
  - Propylene Splitter

- **Coal**
  - Coal-to-Olefins

- **Methanol-to-Olefins**
  - Methanol-to-Propylene

- **Coal-to-Propylene**

- **Refinery Grade Propylene**

- **Ethylene**

- **Polymer grade Propylene**
US NGL production is growing with shale gas and tight oil plays

**NGL production from key shale gas and tight oil plays**

- Permian
- SCOOP
- Woodford
- Utica
- Niobrara
- Marcellus
- Eagle Ford
- Barnett
- Bakken
- Other gas sourced
- Refining

**US lower 48 NGL production by product**

- Natural Gasoline
- Isobutane
- Normal Butane
- Propane
- Ethane

Source: IHS Markit © 2018 IHS Markit
Combination of high crude prices and stable natural gas is attractive for North America gas-based chemical investments.

Source: IHS Markit © 2018 IHS Markit
Ethane cracking is expected to maintain a large cash cost advantage

Ethylene Cast Cost Comparison

Cash cost = Feed + VC + FC – co-product

US Dollar Per Metric Ton

Source: IHS Markit

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NGLs increasingly important to olefins as crackers shift to ethane

Global Ethylene production by feed type (KTA ethylene by feed)

- Ethane, 69,629
- Naphtha, 66,669
- Other, 22,891
- LPG, 13,383
- 2017 (inner) Production = 143 MMTA
- 2022 (outer) Production = 173 MMTA

Propylene production by feedstock

- More ethane for ethylene
- More propane for propylene

Source: IHS Markit © 2018 IHS Markit

3.5 MMTA Ethylene
~ 9 MMTA LPG
Ethylene equivalent trade will continue to expand as the industry builds in low-cost regions and exports to high demand growth regions.

Source: IHS Markit © 2018 IHS Markit
The first wave of US ethane crackers and exports is proceeding but the second wave is uncertain.

US ethane demand and rejection

- **Base Chemical**
- **Price Sensitive**
- **Miscellaneous Fuel**
- **Exports**
- **Rejection**

Source: IHS Markit
Improvements in ethane shipping and capital cost differentials are changing olefins investment patterns

Capital costs in China are currently 50 to 70% of USGC

Can the advantage be sustained?

Similar pattern seen for propylene, but China incentive is stronger
Ethylene cash costs and capital cost advantages make Chinese ethane-based capacity competitive

- Cash costs for ethane cracking in China are higher than in the US due to ethane transport costs
- But - finished product shipping is reduced or eliminated
- In addition, capital cost savings may outweigh the higher operating and feedstock costs
- Ethane cracking capital cost in China is roughly half of naphtha cracking – economics depend on need for co-products
NGL and mixed feed crackers dominate near-term capacity additions

- In addition, over 9 million tons of additional ethane-based units have been announced for China but are still in the planning stages.
- In the US, almost 15 million tons of additional ethane-based capacity is under discussion.
- With annual demand growth of 6 million tons, the capacity will be needed.
- But – is there enough ethane? And where will it be built?
Energy and chemical exports from North America will continue to rise

- Natural gas in North America remains advantaged versus crude
- North America will remain an attractive region for capital investments in base chemicals, derivatives, and feedstocks
- Ethane to China can work - capital versus operating cost dynamics and supply risk tolerance will determine how much is built
- Second wave of ethane crackers will come – but in US or China?
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