Can the US Remain Competitive in Chemicals?
Rice Global E&C Forum

18 May 2018
Rice University | Houston, TX, US
Summary

• Shale is the resource that just keeps giving.
• Capacity additions globally are down from their peak but expected to remain strong through 2022.
• US project costs remain a concern as previous projects were more expensive than expected.
• Current differential between US and China on costs may result in feedstocks instead of products being exported.
Expansions did not happen as anticipated in 2014, but...

**US Basic Chemicals Capacity Additions**

- Total additions 2014 to 2024 currently 84% of previous forecast

**US Spending on Capital Additions**

- Total Spending 2014 to 2024 currently 98% of previous forecast
Agenda

1. Shale Update
2. Factors Impacting where new capacity gets built
3. Updated Global and US outlook
4. Ethylene Example
North American Shale
Innovation found tight oil, now ingenuity is lowering cost per barrel

Median break-even prices for five key US oil plays, 2014–17

![Graph showing median break-even prices for five key US oil plays, 2014–17](image-url)

Notes: The break-even price is the WTI crude oil price required for the project to cover all of its estimated well capital and operating costs and generate a 10% rate of return. Data are through 3Q 2017.
Source: IHS Markit Performance Evaluator

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Productivity improvements provide launch pad for new supply wave

Monthly US crude oil production

Source: IHS Markit, EIA
Long term Brent price environment now expected to average around $70 per barrel (in constant dollars)
Chemical Demand’s Linkage to Economic Activity

**Basic Chemicals**

- Annual Change

**Elasticity**

- Elasticity
- Linear (Elasticity)
Capital investments seek to maximize returns – preferably with a sustainable competitive advantage

**Investment “Drivers”**

- Secure an energy & feedstock advantage
- Leverage current technology and build world-scale for maximum capital efficiency
- Invest with proximity to local markets and/or access to trade routes
- Build to leverage an upstream and/or downstream integrated position

Photo courtesy of Braskem IDESA
Chemicals are illustrative of the energy supply chain. Global chemical demand is concentrated in developing world with more than 50% of demand growth in China…
…But petroleum supply is concentrated elsewhere
Base chemicals produced 492 million tons from 610 million tons of capacity in 2017
Trade from advantaged hydrocarbon regions fills the demand gap – typically at the first value chain node with reasonable logistic costs and product market liquidity.

Volumes greater than 5,000 metric tons noted; intra-regional trade excluded.
All base chemical value-chains are actively adding new capacity on a global basis

Global capacity growth and 2017 total estimates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>170</td>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propylene (PG/CG)</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: IHS Markit

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Global base chemical capacity will increase by 118+ million tons, 2018 – 2022
Asia-Pacific (led by China) will add 60%; N. America – 20%; Middle East – 10%
By all measures, ethylene / propylene / chlor-alkali, will be supply-constrained

**World capacity utilization**

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethylene (Steam Cracker)</th>
<th>Propylene (PG/CG)</th>
<th>Chlorine</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>90%</td>
<td>80%</td>
<td>70%</td>
</tr>
<tr>
<td>2005</td>
<td>95%</td>
<td>85%</td>
<td>75%</td>
</tr>
<tr>
<td>2010</td>
<td>100%</td>
<td>90%</td>
<td>80%</td>
</tr>
<tr>
<td>2015</td>
<td>95%</td>
<td>85%</td>
<td>75%</td>
</tr>
<tr>
<td>2020</td>
<td>90%</td>
<td>80%</td>
<td>70%</td>
</tr>
</tbody>
</table>

**World surplus capacity as % of total demand**

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethylene</th>
<th>Propylene (PG/CG)</th>
<th>Chlorine</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>5%</td>
<td>10%</td>
<td>-5%</td>
</tr>
<tr>
<td>2005</td>
<td>0%</td>
<td>5%</td>
<td>0%</td>
</tr>
<tr>
<td>2010</td>
<td>10%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>2015</td>
<td>5%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>2020</td>
<td>0%</td>
<td>5%</td>
<td>-5%</td>
</tr>
</tbody>
</table>

Source: IHS Markit © 2018 IHS Markit
Capacity additions are moving to take advantage of feedstock availability

Global Additions

Capacity Additions

Source: IHS Markit © 2018 IHS Markit
Global Capacity Additions Spending

Global Basic Chemicals Capacity Additions and Spending

Global Basic Chemicals CAPEX & OPEX Spending

Source: IHS Markit
© 2018 IHS Markit

Spend ($ B) | Additions (MM MT)
US Competitive Advantage Improves as Oil Prices Rise

**World Cost Curve: Polyethylene - HDPE**

- Cumulative Production - Million Metric Tons
- $/Metric Ton
- Source: IHS Markit

**World Cost Curve: Methanol**

- Cumulative Production - Million Metric Tons
- $/Metric Ton
- Source: IHS Markit

- US Plants: 9 plants added with 4.3 million MT of capacity
- US Plants: 7 plants added with 8.4 million MT of capacity

Source: IHS Markit
US Capacity Additions and Spending

US Basic Chemicals Capacity Additions and Spending

Source: IHS Markit
© 2018 IHS Markit

US Basic Chemicals Capacity CAPEX & OPEX Spending

Source: IHS Markit
© 2018 IHS Markit
US Activity has peaked and remains high through 2020

**US Planned Capacity Additions**

- Louisiana – 28%
- Texas - 33%

**US Capacity Additions by Product**

- Ammonia and Methanol – Natural Gas 37%
- Ethylene – Ethane 40%
- Chlorine – Electricity 7%

Source: IHS Markit © 2018 IHS Markit
Concept – Refrigerated liquid versus Pellets
Combination of high crude prices and stable gas is attractive for those North America investments based on natural gas and natural gas liquids

Global crude oil vs. USGC natural gas (2017 Constant $)

Source: IHS Markit
Example of value creation hydrocarbon to polyethylene: a host of market and cost drivers influence ultimate margin realization and value creation

### Cost and Value Drivers for Polyethylene

<table>
<thead>
<tr>
<th>Component</th>
<th>Price, Cost or Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Value</td>
<td></td>
</tr>
<tr>
<td>PL Costs</td>
<td>Ethane Price</td>
</tr>
<tr>
<td>Frac Spread</td>
<td>Ethane Cracking</td>
</tr>
<tr>
<td>Cracker/PO</td>
<td>Price Takers</td>
</tr>
<tr>
<td>OPEX</td>
<td>Commodity PE Selling Price</td>
</tr>
<tr>
<td>Grade Premium</td>
<td>Naphtha Cracking</td>
</tr>
<tr>
<td>Margin</td>
<td>Price Makers</td>
</tr>
<tr>
<td>PE Logistics</td>
<td></td>
</tr>
<tr>
<td>Cracker/PE OPEX</td>
<td></td>
</tr>
<tr>
<td>Naphtha Value</td>
<td></td>
</tr>
</tbody>
</table>

**Ethane Cracking** (Price Takers)

- Commodity PE Selling Price
- Grade Premium

**Naphtha Cracking** (Price Makers)

- Margin
- PE Logistics
- Cracker/PE OPEX
- Naphtha Value
Increase in China’s local content is driving costs down

**Downstream Capital Cost Escalations**

**China Location Factor (CAPEX & OPEX)**

Source: IHS Markit © 2018 IHS Markit
Plenty of value creation available for US investment, but high execution risk as delays and overruns destroy value.
Exports of Propane to China to Produce Propylene is Expanding Rapidly

China Propylene from Imported LPG

Propylene Production Costs - China

Source: IHS Markit
© 2018 IHS Markit
Case study - Multiple models for investment exist to satisfy Chinese demand growth

<table>
<thead>
<tr>
<th>Option</th>
<th>Cash Cost</th>
<th>Capital</th>
<th>Market Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export ethane, build cracking in China</td>
<td>Highest</td>
<td>Lowest</td>
<td>Lowest</td>
</tr>
<tr>
<td>Build US methanol, export to MTO in China</td>
<td>Lowest</td>
<td>Moderate</td>
<td>Medium</td>
</tr>
<tr>
<td>Build ethane cracker in US, export product</td>
<td>Moderate</td>
<td>Highest</td>
<td>Highest</td>
</tr>
</tbody>
</table>
Logistics costs are significant part of cost of imported ethane feedstock in Asia – roughly half of delivered cost to India

Ethane delivered cost build up

Source: IHS Markit © 2018 IHS Markit
Low-cost Chinese and high US capital costs means Chinese investment beats US returns even after accounting for high feedstock shipping costs.
The US still wins on a delivered to customer cash cost basis (and has to or it won’t be able to clear ethane)
At expected ethane prices, cash costs favor naphtha at crude prices below $60/Bbl. Will crude to ethane spreads be low enough for Chinese ethane to beat naphtha?

**Equivalence Graph - Cash Cost For Ethylene**

- **Asian Ethylene vs Brent**
- **Ethylene vs Ethane**
- **Forecast Ethane Delivered China**
  - $500/ton = $10/MMBTU = 67 cpg

**Current Ethane Price Range**

**Ethane ($/Ton)**
- $500/ton

**Brent ($/Bbl)**
- $10/MMBTU

- **67 cpg**
Ethylene Cash cost, capital cost and returns part of the message

World Ethylene Cash Cost Comparison

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

GTO = Gas-to-Olefins; CTO = Coal-to-Olefins; MTO = Methanol-to-Olefins
Announced list of Ethane Crackers Are Under Planning, But How Many Will Come?

<table>
<thead>
<tr>
<th>No.</th>
<th>Company</th>
<th>Location</th>
<th>Major Business</th>
<th>Ethylene Cap/KTA</th>
<th>Consume Ethane/KTA</th>
<th>Investment Billion RMB</th>
<th>Derivatives</th>
<th>Supplier</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Juneng Heavy Industry</td>
<td>Jinzhou, Liaoning</td>
<td>Machinery</td>
<td>2,000</td>
<td>2,600</td>
<td>26.1</td>
<td>NA</td>
<td>American Ethane Company</td>
<td>EIA</td>
</tr>
<tr>
<td>2</td>
<td>Bohai Chemical</td>
<td>Tianjin</td>
<td>Chemical</td>
<td>1,000</td>
<td>1,300</td>
<td>NA</td>
<td>SM, PE</td>
<td>/</td>
<td>FS</td>
</tr>
<tr>
<td>3</td>
<td>Nanshan Group</td>
<td>Yantai, Shandong</td>
<td>Metal</td>
<td>2,000</td>
<td>2,600</td>
<td>26.9</td>
<td>MEO, EVA, PE</td>
<td>American Ethane Company</td>
<td>EIA</td>
</tr>
<tr>
<td>4</td>
<td>Yangmei Hengyuan</td>
<td>Qingdao, Shandong</td>
<td>Coal</td>
<td>1,500</td>
<td>2,000</td>
<td>NA</td>
<td>EDC, SM, PE</td>
<td>American Ethane Company</td>
<td>FS</td>
</tr>
<tr>
<td>5</td>
<td>Satellite PC</td>
<td>Linyungang, Jiangsu</td>
<td>Chemical</td>
<td>2,500</td>
<td>3,250</td>
<td>30.0</td>
<td>EOEIG, PE, EVA</td>
<td>JV with SINOOCO</td>
<td>FS Financing</td>
</tr>
<tr>
<td>6</td>
<td>SP Chemicals</td>
<td>Taixing, Jiangsu</td>
<td>Chemical</td>
<td>650</td>
<td>270</td>
<td>5.5</td>
<td>EDC, SM</td>
<td>E&amp;P, Ineos, one VLEC</td>
<td>Constructing</td>
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<tr>
<td>7</td>
<td>Guangxi Investment</td>
<td>Qinzhou, Guangxi</td>
<td>Power</td>
<td>1,000</td>
<td>1,300</td>
<td>4.5</td>
<td>EOEIG, PE, EVA</td>
<td>/</td>
<td>FS</td>
</tr>
</tbody>
</table>

**TOTAL** | **9,150** | **13,320**
Exports of NGL Feedstocks to China is Already a Reality

US ethane demand and rejection

Source: IHS Markit

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Volume and pace of ethane exports depends on terminal capacity and cracker timing
Conclusions

- **Demand growth concentrated** in developing world and **dislocated** from hydrocarbon supply.
- **Shale** has unlocked huge amounts of **competitive supply** supporting investment growth in Energy and Chemicals.
- Poor US project performance is **eroding** feedstock advantages.
- Future expansion of industry in the US **may be at risk**.