Shale Gas Boom – A New Era of Technology for Ethylene and Ethylene Derivatives

AICHE – Southwest Process Technology Conference
Galveston, Texas
October 4, 2013

Mark W. Lockhart, P.E., Process Technology Manager, Chemicals and Petrochemicals
Elliott Robertson, P.E., Sr. Process Engineer, Chemicals and Petrochemicals
Introduction / Overview

• Shale Gas Boom → C1 – C4’s, Condensate, “Tight Oil”

• Supply / Demand → Pricing Effect

• Ethane based Ethylene → Plant Announcements

• Naphtha/Gas Oil vs Ethane Feeds → SHIFT IN THINKING!

• Ethylene Key Building Block → Much of the Chem / Petrochem Industry is affected

• Chemicals Capacity and Spend → Forecasts
• Increase in Ethylene Supply → Lower pricing

• Ethane → Ethylene → Ethylene Derivatives

• Ethylene in High Supply → Need to Export!!

• Value Chain Focus → EDC, VCM, PVC

• Conclusions → Future looks very bright!!
Shale Gas – Products in High Supply

- High supply vs demand
- Lowers prices
• Shale Gas Having Major Effect on Petrochemical Industry!
  – Lower Energy Costs
  – Lower Feedstock Costs

• U.S. Ethylene Producers:
  – Maximally displacing: Naphtha and Gas Oil → Ethane
  – Currently realizing high profitability
  – Quite a change from earlier last decade

• Ethylene Manufactures Making Moves:
  – Maximizing C2 feed to existing plants → Now
  – Debottlenecking Existing Facilities → 1 to 2 year cycle
  – Building New Grass-roots Ethane-based Crackers → 3 to 4 year cycle
## Ethylene Plant Announcements

<table>
<thead>
<tr>
<th>Company</th>
<th>Project</th>
<th>Capacity, tonnes/year</th>
<th>Location</th>
<th>Cost</th>
<th>Startup</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExxonMobil Chemical</td>
<td>New Cracker</td>
<td>1.5 m</td>
<td>Baytown, TX</td>
<td>NA</td>
<td>2016</td>
</tr>
<tr>
<td>Chevron Phillips Chemical</td>
<td>New Cracker</td>
<td>1.5 m</td>
<td>Cedar Bayou, TX</td>
<td>NA</td>
<td>Q1 2017</td>
</tr>
<tr>
<td>Dow Chemical</td>
<td>New Cracker</td>
<td>World-scale (&gt;800,000m)</td>
<td>U.S. Gulf Coast</td>
<td>NA</td>
<td>2016-2017</td>
</tr>
<tr>
<td>Shell Chemicals</td>
<td>New Cracker</td>
<td>World-scale</td>
<td>U.S. Northeast</td>
<td>NA</td>
<td>2016-2017</td>
</tr>
<tr>
<td>Formosa Plastics</td>
<td>New Cracker</td>
<td>800,000</td>
<td>Point Comfort, TX</td>
<td>$1.7B</td>
<td>2016</td>
</tr>
<tr>
<td>Dow Chemical</td>
<td>Restart</td>
<td>390,000</td>
<td>St. Charles, LA</td>
<td>NA</td>
<td>End 2012</td>
</tr>
<tr>
<td>Westlake Chemical</td>
<td>Expansion</td>
<td>108,863</td>
<td>Lake Charles, LA</td>
<td>NA</td>
<td>Q2 2012</td>
</tr>
<tr>
<td>Williams</td>
<td>Expansion</td>
<td>272,158</td>
<td>Geismar, LA</td>
<td>$350M-$400M</td>
<td>Q3 2013</td>
</tr>
<tr>
<td>INEOS</td>
<td>Debottleneck</td>
<td>115,000</td>
<td>Chocolate Bayou, TX</td>
<td>NA</td>
<td>End 2013</td>
</tr>
<tr>
<td>Westlake Chemical</td>
<td>Expansion</td>
<td>113,399</td>
<td>Lake Charles, LA</td>
<td>NA</td>
<td>2014</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Expansion</td>
<td>366,000</td>
<td>LA Porte, TX</td>
<td>NA</td>
<td>2014</td>
</tr>
<tr>
<td>Westlake Chemical</td>
<td>Expansion</td>
<td>82,000</td>
<td>Calvert City, KY</td>
<td>NA</td>
<td>2014</td>
</tr>
<tr>
<td>Dow Chemical</td>
<td>Expansion</td>
<td>NA</td>
<td>Plaquemine, LA</td>
<td>NA</td>
<td>2015</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Expansion</td>
<td>363,000</td>
<td>Corpus Christi, TX</td>
<td>NA</td>
<td>2015</td>
</tr>
</tbody>
</table>
## Ethylene Plants – Under Consideration

<table>
<thead>
<tr>
<th>Company</th>
<th>Project</th>
<th>Capacity, tonnes/year</th>
<th>Location</th>
<th>Cost</th>
<th>Startup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sasol</td>
<td>New Cracker</td>
<td>1.0M-1.4M</td>
<td>Lake Charles, LA</td>
<td>$3.5B-$4.5B</td>
<td>NA</td>
</tr>
<tr>
<td>Indorama Ventures</td>
<td>New Cracker</td>
<td>World-scale</td>
<td>NA</td>
<td>NA</td>
<td>2017</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Expansion</td>
<td>NA</td>
<td>Channelview, TX</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>SABIC</td>
<td>New Cracker</td>
<td>World-scale</td>
<td>U.S.</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Braskem</td>
<td>New Cracker</td>
<td>World-scale</td>
<td>U.S.</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Occidental Chemical</td>
<td>New Cracker</td>
<td>NA</td>
<td>Ingleside, TX</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>BASF, Total Petrochemicals LLC</td>
<td>New Cracker</td>
<td>NA</td>
<td>Port Arthur, TX</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>BASF, Total Petrochemicals LLC</td>
<td>Expansion (Add 10th C&lt;sub&gt;2&lt;/sub&gt; furnace)</td>
<td>NA (increase by 15%)</td>
<td>Port Arthur, TX</td>
<td>NA</td>
<td>2014</td>
</tr>
</tbody>
</table>

Many producers will include polyethylene plants
Historically Ethylene Feedstocks:
- Naphtha / Gas Oil Based
- Feeds supplied from Refineries
- Tied to the price of Crude Oil

Ethane from Shale Gas:
- New and plentiful source of cracker feed
- Independent of the price of Crude Oil

**THIS IS A MAJOR PARADIGM SHIFT!!!**

Much of the Global Market Steam Cracking will Remain with Naphtha Based Feeds
- This represents a distinct advantage for the U.S.!
Crude Oil versus Natural Gas

Source: IHS, Inc.
Both natural gas and crude prices have contributed to differential performance in the US ethylene industry.

### Cost of Ethylene Production

<table>
<thead>
<tr>
<th>Type</th>
<th>1H'09</th>
<th>Q1'12</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane-based (US)</td>
<td>20</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>Naphtha-based (US)</td>
<td>35</td>
<td>54</td>
<td>19</td>
</tr>
<tr>
<td>Ethylene price (NEA)</td>
<td>34</td>
<td>61</td>
<td>27</td>
</tr>
</tbody>
</table>

Source: CMAI
Ethylene – A Major Building Block

- LDPE
- LLDPE
- HDPE
- Ethylene Dichloride
- Ethylene Oxide
- Ethylbenzene
- Linear Alcohols
- Vinyl Acetate
- Miscellaneous Chemicals
- Polyethylene

- Polyvinyl Chloride (PVC)
- Miscellaneous Fibers
- Polyester Resins
- Polystyrene Resins
- Styrene Acrylonitrile Resins
- Styrene Butadiene Rubber
- Styrene Butadiene Latex
- Miscellaneous
• The purpose of the cracker is to make light olefins (Ethylene and Propylene)
• Shifting to Ethane Feedstock dramatically affects olefin yield
Cracker Co-product Yields

Ton/Ton of Ethylene

- Propylene
- Crude C4/C5
- Pygas
- Fuel Oil
- H2, Methane

- Ethane
- Propane
- Light Naphtha
- Gas Oil
January 2017

Rise of the USGC

- 13 MM MT of capacity added since 2010
- Planned addition currently add 40 MM MT by 2018
- Over 45 MM MT of additional capacity anticipated by 2030

Source: IHS, Inc.
Spending on New Plants Peaks Early

- Total spending from 2013-2030 estimates ~$120B
- Anticipated sharp increase in spending starting in 2014 to peak in 2016 / 2017 at over $13B
- Total spending between 2013-2017 totals nearly $48B

Source: IHS, Inc.
• Where will all of this ethylene production go?
  – Increase in U.S. exports already in progress!!
  – Exports will have to increase significantly as Ethane based capacity comes on line in 2016 / 2017 and beyond
  – Need outlet for balanced supply / demand
  – Ethylene Derivatives much more easily exported

• Ethylene Derivatives forecasted for increased export:
  – Polyethylene
  – Ethylene oxide / Ethylene glycol
  – EDC, VCM, PVC
  – Other

EXPORTS!!
Global Capacity Cost Curve

Raw material factors define regional competitiveness

Source CMAI
Global Ethylene Cost Curve

Source IHS, Inc.
North America Will Become A Major Exporter Of Ethylene Derivatives
Due to low cost of ethylene & chlorine:

• Value chain through PVC forecast to expand
  – New EDC/VCM/PVC capacity
  – By 2017 – 4.1 million MT
  – By 2025 – 9.5 million MT
• Low cost of energy additionally benefits chlorine

Source IHS, Inc.
North America Spending by Product

- Ethylene and Derivatives lead the way
- Chlorine Derivatives follow closely

Source: IHS, Inc.
VCM as Building Block

2011 Total Global Demand = 36 Million Metric Tons

Source IHS, Inc.
AAGR 2007-2017: 5.9 percent

Source: IHS, Inc.
Shale Impact on Vinyl Chain

Most of the World

Oil → Naphtha → Ethylene

Oil → Electricity → Chlor-Alkali

→ EDC  VCM  PVC

North America & Middle East

Natural Gas → Ethane → Ethylene

Natural Gas → Electricity → Chlor-Alkali

→ EDC  VCM  PVC

China

Coal → Carbide → Acetylene

Coal → Electricity → Chlor-Alkali

→ VCM  PVC

Pipe, Siding & Other Fabricated Products

Source IHS, Inc.
EDC VCM Process

Oxy-chlorination

EDC purification

EDC cracking

VCM purification

Ethylene

O₂

Cl₂

HCl recycle

Light ends

EDC recycle

Heavy ends

VCM
### EDC VCM Operating Economics

<table>
<thead>
<tr>
<th>Raw Materials &amp; Products</th>
<th>$(ton/ton-VCM)$</th>
<th>$($/ton)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>462</td>
<td>1320-1362</td>
</tr>
<tr>
<td>Chlorine</td>
<td>578</td>
<td>275-310</td>
</tr>
<tr>
<td>Oxygen</td>
<td>131</td>
<td>40</td>
</tr>
<tr>
<td>EDC</td>
<td></td>
<td>245-275</td>
</tr>
<tr>
<td>VCM</td>
<td></td>
<td>677-820</td>
</tr>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>105</td>
</tr>
<tr>
<td>Steam</td>
<td>Tons</td>
<td>0.15</td>
</tr>
<tr>
<td>Cooling Water</td>
<td>Ft3</td>
<td>6200</td>
</tr>
<tr>
<td>Fuel</td>
<td>Mcal</td>
<td>700</td>
</tr>
</tbody>
</table>
## EDC VCM Capital Economics

<table>
<thead>
<tr>
<th></th>
<th>Years</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Life</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Working Capital</strong></td>
<td>$MM</td>
<td>20</td>
</tr>
<tr>
<td><strong>Direct Production Cost</strong></td>
<td>$MM</td>
<td>189</td>
</tr>
<tr>
<td><strong>Plant Capital Cost</strong></td>
<td>$MM</td>
<td>350</td>
</tr>
<tr>
<td><strong>Fixed Costs</strong></td>
<td>$MM</td>
<td>19</td>
</tr>
<tr>
<td><strong>Gross Income</strong></td>
<td>$MM</td>
<td>80</td>
</tr>
<tr>
<td><strong>Net Profit</strong></td>
<td>$MM</td>
<td>63</td>
</tr>
<tr>
<td><strong>Pay out Period, Years</strong></td>
<td>Years</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Integration with chlorine facilities and availability of ethylene (shale derived) feedstock is key for competitiveness for U.S. VCM producers.

European VCM producers are stunted due to regional financial issues.

Asian VCM producers are still the growth areas but experiencing overbuilt conditions and slower demand than expected.

World economic conditions are restraining chlorine and PVC demand growth but optimistic future is approaching.

Source: IHS, Inc.
• Shale Gas Boom resulting in high production of C1’s-C4’s → Higher supply lowers prices

• Ethane-based Ethylene Plant Announcements → Grass-roots and debottlenecks!!

• Ethylene → Central building block petrochemical → Large sector of U.S. chemical industry affected

• Lower Ethylene prices coming in 2017 ….?

• Ethylene derivatives will benefit → New Capacity
Conclusions

- Where will the increased production go? → EXPORTS!!

- One Example of Ethylene Derivative value chain that is forecasted to benefit: EDC → VCM → PVC

- Also leveraged by Chlorine COP → Low energy prices

- EDC and VCM Economics → Compelling!!

Shale Gas Boom has created a New Era of Technology in the U.S.!!!
Q&A

Burns & McDonnell – 100% Employee Owned!!!

Mark W. Lockhart
mlockhart@burnsmcd.com
832-214-1975

Elliott Robertson
erobertson@burnsmcd.com
832-214-2916