Impact of Shale Gas on the U. S. Petrochemical Industry

CMR FLEXPO, Houston
March 29, 2012
Shale gas is a global phenomenon....

....with nothing in the Middle East
Investments are occurring in many countries

- Countries that are now actively developing shale gas include:
  - Argentina (Chevron Phillips/Apache)
  - China (ExxonMobil)
  - Poland

- Depending upon logistics, government policies and the product portfolio of the developers, petrochemicals could also be produced

- There are significant opportunities in other countries that have large shale gas plays but investments will depend primarily on government priorities and policies. Finding a foreign company to make or share in an investment will be easy
Shale gas is particularly abundant in the United States.

Marcellus is one of the world’s largest plays.
Why are they called *Plays*?

Because the Petrochemical Industry is a Drama!

And we are either in the audience……..

…..or in the Cast!

Remember: All the world is a stage, and all the men and women mere players

William Shakespeare, first petrochemical reporter (“As you like it”)
Now Playing

Shale Gas: The New Frontier
aka
The “Game Changer
Setting the Stage
Shale gas: The New Frontier

- Shale formations are fine grained rock formations that trap natural gas. Shale rock has small pores that are relatively impermeable to natural gas flow unless they are naturally or artificially fractured to create channels connecting the pores so the gas can flow (Sponge).
- Shale gas is present across much of North America in basins of both extreme and moderate size (referred to as “plays”).
- Currently most shale development is concentrated in Marcellus (Appalachia), Barnett (Texas), Haynesville (Louisiana), Fayetteville (Arkansas), Eagle Ford (Texas) and Woodford (Oklahoma).
- The process of setting up the rig, drilling, fracturing, stimulating, and installing operational equipment for a single shale well takes approximately two to eight weeks.
Shale gas composition varies between/within plays

- The ethane content varies from a dry gas (<5%) to a wet gas (6 – 16%)
- The maximum content for heavies for transporting the natural gas is 12% (condensation). The ethane content is so high at some locations that it MUST be extracted prior to shipping
- Western Marcellus is an example of a very rich gas:

<table>
<thead>
<tr>
<th>Composition</th>
<th>Share, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>74.22</td>
</tr>
<tr>
<td>Ethane*</td>
<td>15.62</td>
</tr>
<tr>
<td>Propane*</td>
<td>5.46</td>
</tr>
<tr>
<td>Butane*</td>
<td>1.40</td>
</tr>
<tr>
<td>Pentanes*</td>
<td>1.00</td>
</tr>
<tr>
<td>Hexanes*</td>
<td>1.00</td>
</tr>
<tr>
<td>inerts/other</td>
<td>1.30</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

* heavies

Due to low natural gas prices, developers have been shutting down dry gas wells in favor of wet gas wells to capture the ethane and other NGLs.
Shale deposits are well below the drinking water table; proper drilling procedures should not have drinking water contamination problems.
Fracturing (fracking) is used to make the hard shale rock porous to allow the gas to flow to the wellbore

- Drill 6,000-10,000 feet
- Steel casings
- Cement to stabilize the well and prevent any leakage.
- Drill more
- Explode
- Pump 3 to 4 million gallons of water, mixed with sand and fractional amounts of chemical additives at high pressure, creating cracks in the shale rock beds
- Wellhead
There are some strong environmental concerns

- These include:
  - Environmental safety of the hydraulic fracturing process and the management of the volumes of water used to fracture shale
  - Chemicals used during the fracking process
  - Environmental issues will not stop shale gas development in the key states: PA, LA, TX, WV, et al.

A documentary movie ("Gasland") has been recently made reporting on the environmental problems associated with shale gas developments (visit YouTube for more information)
The Scenery
The key developments have been the ability to drill horizontally and to fracture the shale rock.
Horizontal Drilling reduces the environmental footprint

Traditional development with vertical wells requiring one pad site per well

Multi-well development minimizing surface use with 6-12 wells drilled from a single pad site (surface disturbance <2%)
The shale gas landscape footprint is small

source: University of Pennsylvania study, 6/24/09
The shale gas process
Act One:
A Star is Reborn
The North American petrochemical industry has undergone a dramatic rebirth

- New wave of cracker announcements
  - $16.2 billion in capital investment
  - 17,000 new jobs in the U.S. chemical industry
  - 395,000 additional jobs outside the chemical industry
  - $4.4 billion more in federal, state, and local tax revenue annually ($43.9 billion over 10 years)
  - A $32.8 billion increase in U.S. chemical production
  - $132.4 billion in U.S. economic output

Shale gas has increased natural gas reserves (and petrochemical feedstocks) to more than 100 years (23 MM ft³ current annual consumption vs. reserves of 2.4 trillion ft³)
Ethane has been the favored cracker feedstock

- Shale gas is rich in ethane mainly with propane and butane
- Historically, U. S. crackers were based on 70 percent ethane (NGLs) and 30 percent naphtha (liquids)
- As a result of shale gas and its impact on ethane prices, the ratio has now changed to 87 percent ethane (NGLs) and 13 percent naphtha (liquids). This has dramatically impacted propylene, $C_4$s and aromatics
Oil and natural gas prices have decoupled since 2009.

The spread will likely widen in the future.
The U. S. is at a competitive advantage not seen for the past 20 years.
Impact of shale gas on natural gas prices

![Graph showing the impact of shale gas on natural gas prices](image)
The availability of low-cost ethylene will also change the type of derivative produced

- Before shale gas, many industry experts have said that the production of certain derivatives such as methanol and EG were no longer economically viable for production in the United States
- This is changing
  - Ineos has announced a 500 KTA EG expansion
  - Methanex and Eastman are re-starting methanol plants that have been closed for more than five years due to poor economics
  - Shell will produce EO/EG in its PA cracker

Shale gas has changed the North American petrochemical industry beyond olefins and polyolefins
Act Two:
Domination
Shale gas will be the major source for ethane

The U.S. will become a large net LNG exporter as supply will likely exceed demand
Ethane demand has exceeded supply resulting in price divergence

If this continues, the spread could widen further
Impact of shale gas on US polyethylene competitiveness

2010 Avg. oil price ~ $80/bbl; 2012: $100+

Ethylene price range depending on extent of ethane/natural gas decoupling

North America becomes the second lowest cost producer in the world in either scenario

Source: Chemical Market Resources, Polymer Consulting International
The Cast
Shale gas has led to many new olefins expansion announcements (KTA)

<table>
<thead>
<tr>
<th>Companies</th>
<th>Announcement</th>
<th>Ethylene</th>
<th>Propylene</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayer</td>
<td>Promoting investing at its site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braskem-IDESA</td>
<td>New cracker/PE in Mexico</td>
<td>1,000</td>
<td>0</td>
<td>2015</td>
</tr>
<tr>
<td>Chevron Phillips</td>
<td>Studying new cracker</td>
<td>1,500</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Cunningham Energy</td>
<td>Announced new cracker (WV)</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Dow</td>
<td>Restart St. James cracker</td>
<td>300</td>
<td>-</td>
<td>2014</td>
</tr>
<tr>
<td>Dow</td>
<td>Increase flexibility</td>
<td>NA</td>
<td>-</td>
<td>2014</td>
</tr>
<tr>
<td>Dow</td>
<td>New cracker</td>
<td>1,100+</td>
<td>-</td>
<td>2017</td>
</tr>
<tr>
<td>Dow</td>
<td>PDH</td>
<td>-</td>
<td>~350+</td>
<td>2015</td>
</tr>
<tr>
<td>ExxonMobil*</td>
<td>Incremental expansions</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Formosa Plastics*</td>
<td>Expansion</td>
<td>800</td>
<td>600</td>
<td>2017</td>
</tr>
<tr>
<td>Ineos*</td>
<td>EO/EG : 500 KTA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Debottlenecks</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>LyondellBasell*</td>
<td>Studying new JV cracker</td>
<td>NA</td>
<td>-</td>
<td>2015+</td>
</tr>
<tr>
<td>NOVA</td>
<td>Shale gas to Canada</td>
<td>~900+**</td>
<td>-</td>
<td>2014-17</td>
</tr>
<tr>
<td>Shell</td>
<td>New cracker (JV?)</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Sasol</td>
<td>New cracker</td>
<td>NA</td>
<td>-</td>
<td>2016-18</td>
</tr>
<tr>
<td>Westlake</td>
<td>Debottleneck</td>
<td>110</td>
<td>-</td>
<td>2012-13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>5410***</td>
<td>950+</td>
<td></td>
</tr>
</tbody>
</table>

*needs propylene, **suplemental ethane from Alberta, ****Does not include Shell or Sasol

Every cracker that proceeds must produce polyethylene; some may only produce polyethylene
## Potential polyethylene expansions

<table>
<thead>
<tr>
<th>Expansion status</th>
<th>LLDPE</th>
<th>LDPE</th>
<th>HDPE</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announced new cracker/study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chevron Phillips</td>
<td>X</td>
<td>XX</td>
<td></td>
<td>Possibly as a JV</td>
</tr>
<tr>
<td>Cumberland (Northeast)</td>
<td></td>
<td></td>
<td></td>
<td>Nothing announced on products</td>
</tr>
<tr>
<td>Dow</td>
<td>XX</td>
<td>X</td>
<td></td>
<td>with PDH</td>
</tr>
<tr>
<td>LyondellBasell (study)</td>
<td>X</td>
<td>XX</td>
<td></td>
<td>Possibly as a JV, PDH</td>
</tr>
<tr>
<td>NOVA</td>
<td>XX</td>
<td>X</td>
<td></td>
<td>Will build ~900 KTA AST &amp; NOVAPOL</td>
</tr>
<tr>
<td>Shell (Northeast)</td>
<td></td>
<td></td>
<td></td>
<td>Likely to set up JV for polyethylene</td>
</tr>
<tr>
<td>Sasol</td>
<td></td>
<td></td>
<td></td>
<td>Could set up JV for polyethylene</td>
</tr>
<tr>
<td>Announced debottlenecking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>XX</td>
<td>X</td>
<td></td>
<td>Split/capacity not announced</td>
</tr>
<tr>
<td>Formosa</td>
<td>D</td>
<td>X</td>
<td>D</td>
<td>300 KTA LDPE, some debottlenecking, replace purchased ethylene</td>
</tr>
<tr>
<td>Westlake</td>
<td>X</td>
<td>XX</td>
<td></td>
<td>Split not announced (110+ KTA)</td>
</tr>
<tr>
<td>No ethylene announcement (yet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT Plastics</td>
<td>XX</td>
<td></td>
<td></td>
<td>Not Likely to expand</td>
</tr>
<tr>
<td>DuPont</td>
<td>XX</td>
<td></td>
<td></td>
<td>Major expansion not likely</td>
</tr>
<tr>
<td>Ineos</td>
<td></td>
<td>XX</td>
<td></td>
<td>Only announced 500 KTA EO/EG</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>XX</td>
<td>Likely to expand with recent shale gas investment</td>
</tr>
</tbody>
</table>

D=debottlenecking, XX=most likely, X=secondary focus
The Understudies
There could be additional companies interested in ethylene from shale gas

<table>
<thead>
<tr>
<th>Company</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other North American polyethylene producers</td>
<td></td>
</tr>
<tr>
<td>DuPont</td>
<td>Major expansion not likely (Specialty LDPE)</td>
</tr>
<tr>
<td>Total</td>
<td>Expansion possible; JV with Chesapeake in WV</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential new entrants in ethylene and derivatives</td>
<td></td>
</tr>
<tr>
<td>Braskem, Brazil/USA</td>
<td>Purchased Sunoco; has expressed interest in ethylene derivatives in the US, needs propylene</td>
</tr>
<tr>
<td>Reliance, India</td>
<td>Has invested in three Shale Gas plays; tried to buy LyondellBasell, strong cash position</td>
</tr>
<tr>
<td>SABIC, Saudi Arabia</td>
<td>Major sales effort with polyolefins in the Americas; strong cash position</td>
</tr>
</tbody>
</table>

In addition, some large investments in shale gas have occurred with major foreign companies such as Sinopec
Act Three: War
These developments could also lead to new geographic investments in North America

- Due to the ethane in the Marcellus field, some companies are considering a new cracker in the northeast. Shell has selected Pennsylvania for its new cracker.
- The alternative is to ship the ethane to the Gulf coast via pipeline or barge – both of which are expensive (new pipelines will be required for parts of the route, which may have environmental and other issues).
- NOVA will build a pipeline from Marcellus to Canada for its cracker.

Pennsylvania is where the US oil industry developed in the 1850s. In 1900 Pennsylvania supplied more than 50% of the world’s oil. New York is where the natural gas industry was developed in 1831 using hollow logs to transport the gas.
There will be other pressures

- The ethylene merchant market could be a disaster for sellers and great for buyers
- Companies may over expand in other derivatives
- The “Market Share Wars” begin

There could be a major battle for market share between Gulf Coast and Northeast polyethylene producers

And the winner is....... The Customer
Act Four: Collateral Damage
Shale gas has dramatically affected propylene, C₄s and Aromatics

- Liquid feedstocks such as naphtha have been increasingly replaced with natural gas liquids with more coming
- The change from 70% NGLs/30% liquids to 87% NGLs13% liquids in 2011 has reduced propylene production in crackers by more than 50 percent
- Refineries, which account for about 50 percent of propylene production have remained at 2008 levels
  - Propylene is used in the gasoline pool which is more profitable
  - Would need to revamp refinery product slate to produce substantial quantities of propylene
- Some additional propylene is likely – but not enough to replace current losses and meet future demand
The propylene supply ratio (refinery versus cracker) has been affected by the price shift.

There has been a large percentage shift from crackers to refineries.
Alternative propylene supply options

- Other options:
  - Cracking more propane and butane in flex crackers
  - Metathesis (ethylene trimerization with a C₄ – but C₄s are also very tight). C₄s could be produced via ethylene dimerization. Metathesis is being considered by at least one company (confidential)
  - Propane dehydrogenation (PDH) is an expensive process but low propane prices can support it (Dow, Formosa, others)
  - Methane-to-propylene (MTP) which has some issues such as producing major amounts of methanol and waste water (no known plans)
  - Key decision factor will be the relative economics
Outlook for North American propylene

- No propylene investments in Canada or Mexico
- Short-term, propylene in the United States
- Any outage in a liquids cracker or refinery will adversely impact propylene supply
- Announced on purpose capacity not enough
- About 1.5 million tons per year of new propylene capacity will be needed just to replace the capacity lost to the NGL shift. At a 3% growth rate for propylene derivatives, another 2 million tons per year of new propylene capacity will be needed to meet 2015 projected propylene derivative demand
- Refineries could supply some additional propylene but not enough
US Propylene Demand, By Derivative

- PP 50%
- PO 10%
- Acrylonitrile 9%
- Cumene 9%
- Oxo Alcohols 7%
- Acrylic Acid 5%
- Others 10%

Total Demand for Propylene in US, 2010 = 14,989 KT
Who gets the available propylene?

- Derivatives will compete for the available propylene
- Those using the least amount of propylene per ton of derivative production AND have the ability to pass through the higher cost will get the most propylene (maintain profitability)
- This would result in the following order of supply:
  - Acrylic acid
  - Oxo-Alcohols
  - Cumene
  - Acrylonitrile
  - Propylene Oxide
  - Polypropylene
Impact on polypropylene demand

- Polypropylene could lose about 12% of demand to HDPE, polystyrene/PET. A small amount could also be replaced by paper. Some applications “protected”
- Customers will have to pay higher prices and try to pass them on
- Reduction of U. S. polypropylene exports
- Possible U. S. imports of propylene and propylene derivatives
- Substitution of other derivatives is much more complex and is much more limited (e.g., SAP, specialties, etc.)
Summary

- Shale gas has revitalized the U. S. petrochemical industry with essentially every major ethylene/polyethylene producer planning some level of expansion (2012-2016)
- There could even be additional expansions driven by the natural gas companies, financial companies and other foreign companies
- Essentially all of the capacity will either be exported or replace existing production based on regional competitiveness
- Polyethylene demand growth could accelerate above current forecast levels, especially for LDPE (2 – 3 new LDPE plants could be built based on shale in addition to Mexico)
- The U. S. will have the second best regional export economic position and should dominate Latin America

First movers will have a significant advantage from procurement through construction and market entry
The United States will become a very large net exporter of polyethylene second only to the Middle East. This is a Structural Change that will require a different mindset!

So, are we ready for this or will companies first kill the domestic market trying to sell most of the production domestically (the proverbial Market Share Wars)?

* Good Luck

Or should I say, “Break a Leg!”
The “Shale Gas Plays”

Is it a Comedy?

Is it a Tragedy?

Will it be a Broadway Hit?

Ask me during the intermission.....

......in 2017!