Agenda

- Petrochemical process technology overview
- Impact of shale gas on petrochemical industry
- Shale gas and sustainability
Light Olefin Petrochemical Production Technology

Natural Gas

NGL Recovery Frac

\( C_2, C_3, C_4 \)

Natural Gasoline

Refrigery

\( C_3, C_4 \)

Naphtha, Gas Oil

Crude Oil

Steam Cracking

Ethylene

Butadiene

Mixed Butylenes

Pygas

\( C_5/C_6 \) Non-Arom

BZ/TOL/XYL

Hvy Arom

Fuel Oil

Refined

Propane Dehydro
The Situation 5 Years Ago

- US natural gas production was in decline
- New LNG import terminals were being developed
- US Petrochemical Industry had oversupply of high cost assets
  - High feedstock costs
  - Shrinking domestic demand
  - Trend in off-shoring of manufacturing

Global Investment Focus was on Asia & Middle East Capacity Rationalizations in North America

Source: CMAI 2012
Ethylene Cost of Production

For most petrochemicals:
- > 80% of cost of production is feedstock
- > 10% of cost of production is energy (fuel, steam, power)
- < 5% of cost of production is fixed costs

Feedstock Costs Dominate
US is Price Maker – What Could Change the Picture?
The Shale Revolution

Schematic Geology of Natural Gas Resources

Conventional Gas: Harder to find easier to produce
Unconventional Gas: Easier to find, harder to produce
Figure 1.3 ▶ Shale Gas Production Techniques

IEA 2012 WEO Golden Rules Report
US Shale Plays

Shale Gas and Shale Oil Plays, Lower 48 States

- Shale Gas Plays
- Shale Oil Plays
- Shale Gas and Shale Oil Plays
- Basins
- Stacked Plays
- Shallowest/Youngest
- Deepest/Oldest
Shale Gas Impact on US Production

Figure 107. Natural gas production by source, 1990-2035 (trillion cubic feet)

Shale gas production is projected to account for 49% of total US production in 2035, up from 23% in 2010. Source: DOE/EIA 2012 Annual Energy Outlook
Figure 106. Total U.S. natural gas production, consumption, and net imports, 1990-2035 (trillion cubic feet)

Source: DOE/EIA 2012 Annual Energy Outlook

US Projected to be Net Exporter of Natural Gas around 2022
Shale Gas Impact on Ethane Price

US Gulf Coast Prices

Source: CMAI 2012
**Ethylene Cash Cost Curve**

- **Middle East**
- **North America**
- **NE Asia**
- **SE Asia**
- **Western Europe**

**N. American Feedstock Price Decreasing**

**US Ethane (recent)**

Source: IHS (CMAI)

2011 Curve: 2012 CMAI Conference (Graphical Analysis)

2004 Curve: 2005 World Light Olefins Analysis

**Cost Advantaged Feedstock Changes N. American Position on Cost Curve**
Change in N. American Cost of Production

Ethylene Cash Cost Curve

Source: IHS (CMAI)
2011 Curve: 2012 CMAI Conference (Graphical Analysis)
2004 Curve: 2005 World Light Olefins Analysis

Cost Advantaged Feedstock Changes N. American Position on Cost Curve
Shale Gas Impact on US PC Industry

- Advantaged feedstock position due to shale development
- Strong ethylene demand and operating rates
  - Strong recovery from recession
  - Elimination of significant production capacity from 2008 – 2010
- Attracting Large Investments (Dow, Shell, Others)
- Co-product shortages have led to high prices
  - A result of the shift to light feed slate
  - Increased investments in on-purpose co-product production

Source: CMAI 2011
Shale Gas and Sustainability

- Economic
- Social
- Environmental
Economic Dimension

- **U.S. Petrochemical Industry**
  - Cost advantage feed (from crude oil based naphtha to NGL ethane)
  - Investment in ethylene capacity expansions in progress
  - Investments in co-product production also occurring (propane dehydro, on-purpose BD)

- **Impact on US economy overall through lower energy costs**
  - Lower heating and electricity costs
  - Estimated to save an average of $926 per household between 2012 and 2015 and increase to $2000 per household in 2035
  - Potential to have large impact on transportation costs
  - Gas at $2.50/MMBTU equivalent to $15/eq bbl oil vs. crude at $100/bbl
  - Fleet vehicles already switching over to CNG
  - LNG an option to increase range for long haul freight vehicles
Shale Gas and Sustainability

**Social Dimension**

- **Employment**
  - Direct employment opportunities in shale gas (and oil) industry
  - Indirect jobs in supplying steel, equipment, trucking, support services
  - Direct and indirect shale oil and shale gas supported 1.7 million U.S. jobs this year (IHS Global Insight)
  - Additional jobs supported due industries locating in US to take advantage of lower energy costs vs. relocating overseas (such as PC)

- **Energy Security**
  - US projected to be net natural gas exporter by 2022
  - Shale oil will largely eliminate overseas oil imports by 2020
  - Mitigate Energy Security Threats
    - Political instability of foreign energy producers
    - Price manipulation, competition for resources
    - Natural disasters, terrorism
Shale Gas and Sustainability

**Environmental Dimension**

**Benefits**
- US electricity from gas increased from 20% in 2006 to 25% in 2012, mainly at the expense of coal (decrease in HAP)
- Over past 5 years US GHG emissions declined by 450 MT (largest anywhere in the world)

**Concerns**
- Water Use and treatment and disposal of wastewater
- Contamination of groundwater
- Air emissions (diesel gen sets for fracking wells, trucking, methane)
- Earthquakes (fracking operations intersect existing faults)
- IEA suggest principles for address environmental impacts
- Estimated to increase well costs by 7%

Source: IEA 2012 WEO Golden Rules Report
Summary

- Shale gas has already had a dramatic impact on US Petrochemical Industry and US energy supply

- Positive impacts with respect to employment and security on the social dimension

- Environmental impact
  - Replace coal with cleaner burning natural gas
  - Concerns with shale gas production are real
  - Cost effective solutions have been proposed to effectively manage these risks

*Shale Gas/Oil can be a Bridge to the Future. Renewables R&D Still Required.*
Source Data

- IHS/CMAI - North American Olefins Overview - 2012
- IEA World Energy Outlook 2012
- DOE/EIA, Annual Energy Outlook 2012
- The Future of Natural Gas, MIT Study 2010
- Gas works, Economist, July 2012