Implementation Challenges and Risk Mitigation for New Technology

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AICHE 2016 Natural Gas Utilization Conference, Morgantown WV, November 1-4, 2016
Responding to Uncertainty

WEEKLY WORLD NEWS
THE WORLD’S ONLY RELIABLE NEWSPAPER

WHAT THE GOVERNMENT DOESN’T WANT YOU TO KNOW...

NO MORE OIL!
WORLD SUPPLY WILL BE GONE IN 6 MONTHS

• ECONOMY WILL COLLAPSE!
• MILLIONS WILL STARVE!

DOW OLEFINS, AROMATICS AND ALTERNATIVES
A New Opportunity or Threat?

WEEKLY WORLD

OIL FOUND ON MOON!

Gas prices will fall to 10¢ a gallon as Arab oil becomes obsolete!

Dow Olefins, Aromatics and Alternatives
Strategic Response

Advantaged Positions Across the Globe

- **USGC Investments**
  - US shale

- **Sadara**
  - Low cost
  - Access to Asia

- **Revamped Alberta Advantage**
  - Alberta advantage

- **European LPG**
  - Extending US shale advantage
  - Abundant LPG for Europe

- **Established Key Alliances in Latin America**
  - Growing ethane
  - Next large shale development

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R&D evaluates, develops and deploys technology options for different scenarios

2014 Dow Investor Forum (http://www.dow.com/investors/)

Dow Olefins, Aromatics and Alternatives
Innovation: The economically successful commercialization of a technology providing an unmet need or significant advantage over the next best alternative.
Technology Innovation Requirements

1. Market opportunity is available
2. Need-meeting technology is ready
3. Investment support in place

Innovation only occurs when these events intersect

Technology and Commercialization Plan must be complete prior to alignment to insure quick and robust execution
Implementation Challenges

Low Ability to Mitigate Challenges

Feedstock Market Conditions
Technology Readiness
Investment Cycle/Strategy

Price Volatility
Supply Security
Infrastructure
RM Quality
RM Logistics
Geography

Catalyst
Expertise in Area
Lab capabilities
IP Strategy/RTP
Process Equipment
BPCS/LOPA

Funding Availability
Regulatory
Tax implications
Financing Rates
Extent of Leverage
Partnerships

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Mitigating Feedstock Market Challenges

- Seek new opportunities that add flexibility
- Understand what drives volatility
- Take advantage of market floor/ceilings
- Look for preferential geographies
US Chemical Expansion: Driven by Cheap Shale-gas

- Abundant shale gas in North America → shift of feedstock in petrochemical industry from more naphtha to LPG
- Less propylene production from steam cracking
- On-purpose propylene production to close the gap

Dow’s Shale Gas Driven US Expansion: Investing >$4 billion into US Gulf Coast Operations
Outlook for Feedstock Supply Favorable

Dow’s View on Market Drivers
- Favorable balances through next several years
  - Gas well supplied
  - NGL supplies grow with associated gas
  - Forecasts include exports and new crackers

Propane supply/demand remains soft
- Propane prices below naphtha
- Propane has historically – and will continue to – cap ethane price

Source: Dow

Source: Dow, Bloomberg, US EIA, SGX, Liquidity Partners
Mitigating Technology Risk:

- Use a stage gate approach to assess TRL
- Get key stakeholder buy-in at beginning
- Determine shortcomings and comparisons with NBA
- Utilize Strategic partnerships
- Hire expertise if not available internally
- Build upon and learn from the past
- Utilize equipment suitable for the process
- Use your best most advanced tools
- Set ambitious targets—both CAPEX/OPEX
- Utilize catalyst vendors for scale-up
- Clear implementation plan for first commercialization with contingencies
Evolution of Catalytic Cracking Processes
Technology will converge to the Best Economic Solution
The question is .....When?

**Gasoline**

- Houdry 1936\(^{(22)}\)
- Moving Bed 1938\(^{(22)}\)
- FCC 1942\(^{(22)}\)
- FCC/Riser/Zeolite 1960-65\(^{(22)}\)
- 2 Stage RG 1972\(^{(22)}\)

**Styrene**

- Axial Adiabatic 1940\(^{(23)}\)
- Heated Case 1965\(^{(23)}\)
- Radial Adiabatic 1972\(^{(23)}\)
- SNOW Process 2005

**Propylene**

- FCC Byproduct
- Steam Cracking Byproduct
- CATOFIN® Unit (c4) 1980's\(^{(12)}\)
- OLEFLEX™ Unit 1990\(^{(11)}\)

Dow Olefins, Aromatics and Alternatives
# Current Commercial PDH Technologies and Dow Fluidized Catalytic Dehydrogenation (FCDh)

<table>
<thead>
<tr>
<th></th>
<th>Oleflex™</th>
<th>Catofin®</th>
<th>Dow PDH</th>
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</thead>
<tbody>
<tr>
<td><strong>Reactor</strong></td>
<td><img src="image1" alt="Multi-stage, adiabatic, moving bed reactor, CCR Regenerator" /></td>
<td><img src="image2" alt="Multi-reactor, Adiabatic Fixed-bed" /></td>
<td><img src="image3" alt="1 Proprietary Fluidized Reactor" /></td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td><img src="image4" alt="Oleflex Process Flow" /></td>
<td><img src="image5" alt="Chromia/alumina" /></td>
<td><img src="image6" alt="Ga-Pt/alumina" /></td>
</tr>
<tr>
<td><strong>Catalyst</strong></td>
<td>Pt-Sn/alumina</td>
<td>Chromia/alumina</td>
<td>Ga-Pt/alumina</td>
</tr>
<tr>
<td><strong>Reactor Outlet Pressure, psia</strong></td>
<td>16-24 psia</td>
<td>7 psia</td>
<td>19-25 psia</td>
</tr>
<tr>
<td><strong>Conv. per pass</strong></td>
<td>35 - 40%</td>
<td>48 - 53%</td>
<td>43-53%</td>
</tr>
<tr>
<td><strong>Sel. to C3=, mol%</strong></td>
<td>89%@ XX conv; 84% @ 40% conv</td>
<td>86+ @ XX% conv</td>
<td>92-96% @ 43%-48% conv</td>
</tr>
</tbody>
</table>

*Oleflex™ and Catofin® info. from process brochure, presentation, journal publication and patent literature*
Dow Catalytic Dehydrogenation Technology

Delivers Significant Capital and Operating Cost Advantage over existing commercialized technologies

Circulating fluid bed technology for reaction and regeneration

- Lowest Energy Cost (20% reduction)
- Lowest Raw Material Consumption (5% lower unit ratio)
- Lowest capital cost outlay
  - Simple 1 regenerator and 1 reactor system without furnaces
  - 25% less capital (including catalyst)
- Sustainable technology: Low NO\textsubscript{x} and CO\textsubscript{2} emissions

Based on proven FCC technology

- Invested in and Partnered with FCC Experts for over 10 years
- Leveraged FCC know-how from industry
- Design variations from FCC validated
  - Pilot Plants
  - Models
- Reliable production
  - FCC Plants routinely operate 4-6 years between turnarounds
  - Catalyst can be continuously replaced as needed
Catalyst for Dow PDH

Catalyst: GaOx Supported on Fluidizable Alumina with Pt promoter
- Ga is the key dehydrogenation ingredient
- Trace amount of Pt important for fuel combustion
The Dow Catalytic Dehydrogenation Process is a Platform Reactor Technology

- Most economical PDH technology that can integrate with a cracker
- Plants scale down at attractive capital intensity
- Reactor technology can plug and play into multiple plant configurations

**Multiple Chemistries**
- EB $\rightarrow$ Styrene
- Propane $\rightarrow$ Propylene
- Butane $\rightarrow$ Butene
- Isobutane $\rightarrow$ Isobutene
Dow Catalytic Dehydrogenation Technology Development History: Ready for Commercialization

- Index and Process Flow Sheets are Complete
- Reactor/Regenerator Design Complete
- Layers of Protection Analysis Complete
- Process and Instrumentation Diagrams Complete
- IP Portfolio Growing and Robust (>20 applications 3 key grants)
- Scale-up Plan uses a multi-faceted approach
Thank You!