Crude to Chemicals

Opportunities and Challenges of an Industry Game-Changer

MERTC, Bahrain

January 23, 2017
This presentation contains forward-looking statements regarding CB&I and represents our expectations and beliefs concerning future events. These forward-looking statements are intended to be covered by the safe harbor for forward-looking statements provided by the Private Securities Litigation Reform Act of 1995. Forward-looking statements involve known and unknown risks and uncertainties. When considering any statements that are predictive in nature, depend upon or refer to future events or conditions, or use or contain words, terms, phrases or expressions such as “achieve,” “forecast,” “plan,” “propose,” “strategy,” “envision,” “hope,” “will,” “continue,” “potential,” “expect,” “believe,” “anticipate,” “project,” “estimate,” “predict,” “intend,” “should,” “could,” “may,” “might” or similar forward-looking statements, we refer you to the cautionary statements concerning risk factors and “Forward-Looking Statements” described under “Risk Factors” in Item 1A of our Annual Report filed on Form 10-K filed with the SEC for the year ended December 31, 2015, and any updates to those risk factors or “Forward-Looking Statements” included in our subsequent Quarterly Reports on Form 10-Q filed with the SEC, which cautionary statements are incorporated herein by reference.
A Leading Provider of Technology and Infrastructure for the Energy Industry

- ~40,000 employees
- Breadth of services from wellhead to polymers
- Recent technology portfolio expansions
  - LC-Fining → LC-Max → LC-Slurry ... >99% conversion of crude
  - Start up of world’s largest PX unit (2,200 KTA) at Reliance
  - AlkyClean (solid acid catalysis alkylation) - in operation
  - E-Gas: Coke & Pitch – world’s largest gasification unit - 2017 start up at Reliance
  - NET Power – superheated CO₂ cycle - 50 MW demo unit in construction
For more than 100 years, Lummus Technology has been recognized as one of the energy industry’s leading providers of licensed process technology.

- CB&I acquired Lummus Technology in 2007 and has been developing and expanding the technology portfolio for 10 years.
- Our robust technology offering and legacy of excellence in engineering and construction are unmatched in the industry.

LUMMUS TECHNOLOGY IS CB&I
Ethylene growth rate continues to be 4-5% per year
Percentage of ethylene from ethane increasing driven by North America
Limited supply of ethane in most of GCC → shift to liquid feeds
Where will crackers be built?
- Gas crackers in North America
- Liquid crackers in Middle East and Asia
Recent Industry Trends – Refined Products

- Refined products landscape has changed
  - ~1% growth in refined products
  - Gasoline demand remains flat
  - Increased supply of NGLs
  - Distillate demand growth modest
  - IMO sulfur specs for bunker fuel to be implemented 2020 → fuel oil reduction
- Oil prices volatile (~ $45-55/Bbl)
- Multiple supply sources make oil prices unpredictable:
  - OPEC initiatives to manage supply
  - US tight oil resilient
  - Canadian syncrude production flat
- Crude volatility +/- 100%
- Polymer volatility +/- 40%

Greater petrochemical price stability drives advantage to monetize crude by conversion to petrochemical products
The ethylene cracker is the heart of the petrochemical production center

Feedstock flexibility is required (ethane → VGO)

Optimal utilization of C₄s depends on local economics

Control of propylene to ethylene ratio

OCT (Olefins Conversion Technology) provides lower cost conversion flexibility to produce propylene / ethylene / butylenes

<table>
<thead>
<tr>
<th>Ethylene Plant Configuration</th>
<th>Ethylene Plant with C₄ Recycle</th>
<th>BD + OCT unit</th>
<th>Only OCT unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butadiene Recovery</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Propylene-to-Ethylene Ratio</td>
<td>0.68</td>
<td>0.83</td>
<td>1.01</td>
</tr>
</tbody>
</table>
OCT – Maximum Flexibility

- **Ethylene Feed**
- **C₄ Feed**
- **OCT Reactor**
- **OCT Treater**
- **Deethylenizer**
- **Depropylenizer**
- **Recycle Ethylene**
- **Lights Purge**
- **Propylene Product**

**Flow Rates:**
- 100 kta Ethylene
- 200 kta Butene
- 300 kta Propylene
Crude to Chemicals
Change in Mindset in OTC

Traditional

CRUDE

Fixed Barrels

OTC

CRUDE

Transportation Fuels (Optional)

Fixed Qty. In KTA

Chemicals

Transportation Fuels

Chemicals

A World of Solutions
A World of Solutions

- Polynuclear aromatics
  - Lowest olefin yields
  - High coking rate
- Residue
  - Extreme coking rate
  - Contains asphaltenes that are difficult to vaporize
    - Solids (asphaltenes and coke) will form during vaporization and cracking
    - Asphaltenes are soluble in aromatics and insoluble in paraffins
    - Coke is insoluble in both
- Direct crude cracking can be achieved using Heavy Oil Processing Scheme (HOPS)
- Lummus patented the HOPS
  - 4 units were designed and commissioned
  - Elimination of CDU and/or VDU with multi-stage HOPS
  - Lowest investment solution

Number of HOPS stage dependent on crude gravity
What are the Challenges?

Typically the heaviest material (residue) must be removed before cracking.

Crude residue fraction much larger.
CB&I HOPS technology successfully employed for condensates and extra light crudes

Potential large volume of residue to be sold

For most crudes an intermediate step is essential

Mainly a niche application

Miracle of hydrogen addition
The Miracle of Hydrogen Addition

Hydrocracking of Residue and Distillates Provides the most efficient route to feeding the Ethylene Cracker in terms of Feed Flexibility AND Conversion Yield

>2.0 MM MTA of Ethylene can be produced from 140,000 – 200,000 BPSD of AL Crude depending on flowscheme
Crude to Chemicals Configurations

Matching the Refinery & the Chemicals
- No Residue Upgrading
- Hydrocracking to produce cracker feed
- Produce HSFO
- Maximum petrochemicals / No fuels production

**Minimum Investment; No Resid Upgrader; No Fuels; Sell HSFO**

<table>
<thead>
<tr>
<th>Product</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude (Arab Light), BPD</td>
<td>195,000</td>
</tr>
<tr>
<td>Ethylene, KTA</td>
<td>2,000</td>
</tr>
<tr>
<td>Propylene, KTA</td>
<td>1,480</td>
</tr>
<tr>
<td>Butadiene, KTA</td>
<td>357</td>
</tr>
<tr>
<td>Euro VI Diesel, BPD</td>
<td>0</td>
</tr>
<tr>
<td>Fuel Oil, BPD</td>
<td>54,000</td>
</tr>
<tr>
<td>Anode Coke, KTA</td>
<td>0</td>
</tr>
<tr>
<td>H2 Required, MMSCFD</td>
<td>167</td>
</tr>
<tr>
<td>% Required H2 from Cracker</td>
<td>39</td>
</tr>
<tr>
<td>Natural Gas Required, KTA</td>
<td>596</td>
</tr>
<tr>
<td>Chemical Yield on Crude, %</td>
<td>58</td>
</tr>
<tr>
<td>Total Project Cost, MM$</td>
<td>6,954</td>
</tr>
<tr>
<td>%IRR</td>
<td>14.6</td>
</tr>
<tr>
<td>3%S HSFO</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. All cases includes Hydrocracker + Olefins Conversion Technology
2. All cases produces MTBE, Butene-1, Benzene, Xylenes
3. 3% HSFO priced at $21/Bbl less than crude
4. %IRR based on 70 / 30 debt / equity ratio
- Residue Hydrocracking offers maximum conversion and crude flexibility
- LC-FINING as Residue Upgrading
- Hydrocracking to produce cracker feed
- Produce LSFO
- Maximum petrochemicals / No fuels production

**Ethylene Cracker Complex + Olefins Conversion Technology**

<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude (Arab Light), BPD</td>
<td>162,000</td>
</tr>
<tr>
<td>Ethylene, KTA</td>
<td>2,000</td>
</tr>
<tr>
<td>Propylene, KTA</td>
<td>1,493</td>
</tr>
<tr>
<td>Butadiene, KTA</td>
<td>358</td>
</tr>
<tr>
<td>Euro VI Diesel, BPD</td>
<td>0</td>
</tr>
<tr>
<td>Fuel Oil, BPD</td>
<td>25,000</td>
</tr>
<tr>
<td>Anode Coke, KTA</td>
<td>0</td>
</tr>
<tr>
<td>H2 Required, MMSCFD</td>
<td>251</td>
</tr>
<tr>
<td>% Required H2 from Cracker</td>
<td>26</td>
</tr>
<tr>
<td>Natural Gas Required, KTA</td>
<td>777</td>
</tr>
<tr>
<td>Chemical Yield on Crude, %</td>
<td>70</td>
</tr>
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<td>Total Project Cost, MM$</td>
<td>7,995</td>
</tr>
<tr>
<td>%IRR</td>
<td>22.4</td>
</tr>
</tbody>
</table>

**Notes**
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- LC-FINING as Residue Upgrading
- Hydrocracking to produce cracker feed
- Produce LSFO
- Fuels production

**LC-FINING With Fuels; Sell LSFO**

<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity/BPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude (Arab Light)</td>
<td>227,000</td>
</tr>
<tr>
<td>Ethylene, KTA</td>
<td>2,000</td>
</tr>
<tr>
<td>Propylene, KTA</td>
<td>1,469</td>
</tr>
<tr>
<td>Butadiene, KTA</td>
<td>347</td>
</tr>
<tr>
<td>Euro VI Diesel, BPD</td>
<td>74,500</td>
</tr>
<tr>
<td>Fuel Oil, BPD</td>
<td>20,000</td>
</tr>
<tr>
<td>Anode Coke, KTA</td>
<td>0</td>
</tr>
<tr>
<td>H2 Required, MMSCFD</td>
<td>379</td>
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<tr>
<td>% Required H2 from Cracker</td>
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<tr>
<td>Natural Gas Required, KTA</td>
<td>1,011</td>
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<tr>
<td>Chemical Yield on Crude, %</td>
<td>49</td>
</tr>
<tr>
<td>Total Project Cost, MM$</td>
<td>8,910</td>
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<tr>
<td>%IRR</td>
<td>24.4</td>
</tr>
<tr>
<td>1%S LSFO</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. All cases includes Hydrocracker + Olefins Conversion Technology
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LC-FINING – With Fuels – LSFO

- LC-FINING as Residue Upgrading
- Hydrocracking to produce cracker feed
- Produce LSFO
- Fuels production

Notes
1. All cases includes Hydrocracker + Olefins Conversion Technology
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LC-FINING + Delayed Coking: No Fuels/No Fuel Oil – Anode Coke

- LC-FINING + DCU
- Hydrocracking to produce cracker feed
- Produce anode coke
- Maximum petrochemicals / No fuels production

<table>
<thead>
<tr>
<th>Ethylene Cracker Complex + Olefins Conversion Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene 2,000 KTA</td>
</tr>
<tr>
<td>Propylene</td>
</tr>
<tr>
<td>Butene-1</td>
</tr>
<tr>
<td>Butadiene</td>
</tr>
<tr>
<td>MTBE</td>
</tr>
<tr>
<td>Benzene</td>
</tr>
<tr>
<td>Mixed Xylenes</td>
</tr>
</tbody>
</table>

Crude (Arab Light), BPD | 137,689 |
Ethylene, KTA          | 2,000   |
Propylene, KTA         | 1,481   |
Butadiene, KTA         | 373     |
Euro VI Diesel, BPD    | 0       |
Fuel Oil, BPD          | 0       |
Anode Coke, KTA        | 194     |
H2 Required, MMSCFD    | 282     |
% Required H2 from Cracker | 24 |
Natural Gas Required, KTA | 794 |
Chemical Yield on Crude, % | 83 |
Total Project Cost, MM$ | 8,492 |
%IRR                     | 21.4    |

Anode Coke

Notes:
1. All cases includes Hydrocracker + Olefins Conversion Technology
2. All cases produces MTBE, Butene-1, Benzene, Xylenes
3. 3% HSFO priced at $21/Bbl less than crude
4. %IRR based on 70 / 30 debt / equity ratio
- **LC-Slurry**
- Hydrocracking to produce cracker feed
- Petrochemicals with fuels production

**Ethylene Cracker Complex + Olefins Conversion Technology**

- Naphtha, C2, LPG
- Hydrogen
- Py. Oil
- VGO

**Outputs:**
- Ethylene 2,000 KTA
- Propylene
- Butadiene
- Benzene
- MTBE
- Mixed Xylenes
- Euro V / VI Diesel 106,000 BPD
- Fuel Oil, BPD 8,500
- Crude (Arab Light), BPD 246,515
- Ethylene, KTA 2,000
- Propylene, KTA 1,489
- Butadiene, KTA 326
- Euro VI Diesel, BPD 106,000
- Fuel Oil, BPD 8,500
- Anode Coke, KTA 0
- H2 Required, MMSCFD 417
- % Required H2 from Cracker 16
- Natural Gas Required, KTA 992
- Chemical Yield on Crude, % 45
- Total Project Cost, MMS 9,285
- %IRR 25.0

**Notes**
1. All cases includes Hydrocracker + Olefins Conversion Technology
2. All cases produces MTBE, Butene-1, Benzene, Xylenes
3. 3% HSFO priced at $21/Bbl less than crude
4. %IRR based on 70 / 30 debt / equity ratio
- Crude Flexibility: design balances light and heavy crudes
  - Opportunity of low cost crudes without excessive CAPEX

- Residue upgrading depends on:
  - Quantity / quality of transportation fuels & fuel oil
  - Power/hydrogen strategy
    - Gasification provides flexibility where natural gas has limited availability
  - Middle of the barrel processing objectives
  - Hydrogen production strategy

- Middle of the barrel processing depends on desired product slate:
  - Lubes
  - Gasoline vs. Jet vs. Diesel
  - Aromatics
  - High quality / quantity of cracker feed

- High on-stream factor: match refining to petrochemicals
## Analysis of Crude to Chemicals Complexes: Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Minimum Investment; No Resid Upgrader; No Fuels; Sell HSFO</th>
<th>LC-FINING; No Fuels; Sell LSFO</th>
<th>LC-FINING With Fuels; Sell LSFO</th>
<th>LC-FINING With Fuels; Sell LSFO - Two Train Cracker</th>
<th>LC-FINING + Delayed Coking; No Fuels; Produce Anode Coke</th>
<th>LC-Slurry With Fuels; Produce ULSFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude (Arab Light), BPD</td>
<td>195,000</td>
<td>162,000</td>
<td>227,000</td>
<td>400,000</td>
<td>137,689</td>
<td>246,515</td>
</tr>
<tr>
<td>Ethylene, KTA</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
<td>4,000</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Propylene, KTA</td>
<td>1,480</td>
<td>1,493</td>
<td>1,469</td>
<td>2,805</td>
<td>1,481</td>
<td>1,489</td>
</tr>
<tr>
<td>Butadiene, KTA</td>
<td>357</td>
<td>358</td>
<td>347</td>
<td>774</td>
<td>373</td>
<td>326</td>
</tr>
<tr>
<td>Euro VI Diesel, BPD</td>
<td>0</td>
<td>0</td>
<td>74,500</td>
<td>94,265</td>
<td>0</td>
<td>106,000</td>
</tr>
<tr>
<td>Fuel Oil, BPD</td>
<td>54,000</td>
<td>25,000</td>
<td>20,000</td>
<td>36,935</td>
<td>0</td>
<td>8,500</td>
</tr>
<tr>
<td>Anode Coke, KTA</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>194</td>
<td>0</td>
</tr>
<tr>
<td>H2 Required, MMSCFD</td>
<td>167</td>
<td>251</td>
<td>379</td>
<td>665</td>
<td>282</td>
<td>417</td>
</tr>
<tr>
<td>% Required H2 from Cracker</td>
<td>39</td>
<td>26</td>
<td>18</td>
<td>22</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Natural Gas Required, KTA</td>
<td>596</td>
<td>777</td>
<td>1,011</td>
<td>1,872</td>
<td>794</td>
<td>992</td>
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<tr>
<td>Chemical Yield on Crude, %</td>
<td>58</td>
<td>70</td>
<td>49</td>
<td>57</td>
<td>83</td>
<td>45</td>
</tr>
<tr>
<td>Total Project Cost, MM$</td>
<td>6,954</td>
<td>7,995</td>
<td>8,910</td>
<td>14,173</td>
<td>8,492</td>
<td>9,285</td>
</tr>
<tr>
<td>%IRR</td>
<td>14.6</td>
<td>22.4</td>
<td>24.4</td>
<td>33.0</td>
<td>21.4</td>
<td>25.0</td>
</tr>
</tbody>
</table>

### Notes

1. 3%S HSFO 1%S LSFO 1%S LSFO 1%S LSFO Anode Coke 0.1%S ULSFO
2. All cases includes Hydrocracker + Olefins Conversion Technology
3. All cases produces MTBE, Butene-1, Benzene, Xylenes
4. 3% HSFO priced at $21/Bbl less than crude
5. %IRR based on 70 / 30 debt / equity ratio
- CB&I/CLG has a complete technology portfolio to upgrade ANY crude to chemicals in the most cost effective manner

- HOPS technology successfully implemented for condensate / low residue crudes, but limited by crude slate

- Hydrocracking provides optimum cracker feed quality

- LC-FINING / LC-Slurry with or without fuels has good economics

- Best economics achieved with world scale cracker and refinery capacity