UOP ADVANCED MTO™ PROCESS

Natural Gas Monetization to Polyolefins

UOP Olefins Seminar; Efficient Monetization of Natural Gas and LPG

UOP Limited – Richard Smith
December 2016
Agenda

• Natural Gas to Polyolefins Value Chain

• What is UOP Advanced MTO Technology?

• Commercially Proven Technology

• Why is UOP Advanced MTO the best choice?

• Summary
Natural Gas to Polyolefin Value Chain

Methanol to Olefins Technology Key to Value Addition

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UOP Advanced MTO Yield Performance

Technology Comparison

C2= + C3= Carbon Yield %

- Ethylene
- Propylene

Naphtha  MTP  MTO  Advanced MTO

UOP Advanced MTO yields = highest added value
Overall Block Flow Diagram

UOP Advanced MTO Technology

CH₃OH

H₂O

C₄=+

C₂= + C₃=

Olefin Cracking Process (OCP)

Olefin Purification Unit (OPU)

C₂=

C₃=

C₄=+ By-Product

All Sections Commercially Proven

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Reactor / Regenerator Section (Rx/Rg)

**UOP has >200 fluidized bed units in operation**

Smallest Rx/Rg and least compression = Lower CapEx.

Fast fluidized bed reactor design utilizing UOP’s extensive FCC experience

Lowest catalyst inventory and makeup rate = Lower OpEx.

UOP has >200 fluidized bed units in operation

Smallest Rx/Rg and least compression = Lower CapEx.

Highest olefin yield

No CO Boiler. Lowest downtime/maintenance.

Dry Products to OPU

To / From OCP

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Olefin Cracking Process (OCP)

**Increases** $C_2^+ + C_3^+$ yield by 15 – 20%.

Feeds from Product Separation & Olefin Purification

Fixed bed reactor system. 
*Low CapEx, Low OpEx vs. Fluidized Bed*

**Light Olefin Product to Product Separation**

**Depropanizer Column**

**C$_4^+$ By-Products**

**Olefin Cracking Reactor**

**Recycle Column**

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Olefin Purification Unit (OPU)*

**Highest C2= & C3= product recovery**

**No De-Methanizer Required – Low OpEx**

Dry Products from Product Separation

Single refrigeration system. Low CapEx

Utilized in operating UOP Advanced MTO Units

*UOP/Wison Partnership

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## Commercialization Status

<table>
<thead>
<tr>
<th>#</th>
<th>Owner</th>
<th>Location</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Wison (Nanjing) Clean Energy Company, Ltd.</td>
<td>Nanjing, Jiangsu</td>
<td>Onstream 2013</td>
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<tr>
<td>2</td>
<td>Jiutai Energy (Zhungeer) Company, Ltd.</td>
<td>Ordos, Inner Mongolia</td>
<td>SU 2017</td>
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<tr>
<td>3</td>
<td>Shandong Yangmei Hengtong Chemicals Company, Ltd.</td>
<td>Linyi, Shandong</td>
<td>Onstream 2015</td>
</tr>
<tr>
<td>4</td>
<td>Jiangsu-Sailboat</td>
<td>Lianyungang, Jiangsu</td>
<td>SU Dec 2016</td>
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<tr>
<td>5</td>
<td>Shandong Better Energy</td>
<td>Dongying, Shandong</td>
<td>Awarded</td>
</tr>
<tr>
<td>6</td>
<td>Undisclosed</td>
<td>China</td>
<td>SU 2018</td>
</tr>
<tr>
<td>7</td>
<td>Undisclosed</td>
<td>China</td>
<td>Awarded</td>
</tr>
<tr>
<td>8</td>
<td>LUXI Chemical Group Co. Ltd.</td>
<td>Liaocheng, Shandong</td>
<td>Design</td>
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<tr>
<td>9</td>
<td>Connell Chemical Industrial Co. Ltd.</td>
<td>Jilin City, Jilin</td>
<td>SU 2017</td>
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</tbody>
</table>

Units ranging from 300kMTA – 830kMTA of total \( \text{C}_2= + \text{C}_3= \)
Nanjing MTO Plant Construction – July 2013

300kMTA of Ethylene + Propylene
Operating since 2013
UOP Advanced MTO Unit: Jiangsu Sailboat

830kMTA of Ethylene + Propylene
Currently in start-up phase
P/E Ratio vs Total Ethylene and Propylene Yield

P/E Ratio vs Yield

UOP Advanced MTO technology has P/E ratio operating flexibility
UOP Advanced MTO Technology Performance Analysis Basis

- MTO Unit Capacity
  - 1650KMTA MeOH

- Price Sets:

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<tr>
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<tbody>
<tr>
<td>Methanol Feed</td>
<td>330*</td>
<td>290</td>
<td>230</td>
</tr>
<tr>
<td>Ethylene</td>
<td>1160*</td>
<td>1160*</td>
<td>1130*</td>
</tr>
<tr>
<td>Propylene</td>
<td>1120*</td>
<td>1120*</td>
<td>815*</td>
</tr>
</tbody>
</table>

- Economic Basis
  - Methanol to Olefins
  - 10% Discounting Rate
  - 3 years unit construction with 20%/30%/50% capital spend, 20 years cash inflow
  - UOP Advanced MTO total CapEx $455M (ISBL + 30% cost allowance).
  - MTO Unit terminal value of 20% of CapEx
  - 30% equity / 70% debt funding
  - Catalyst and Utility allowance included

* Source - IHS
Highest Total Ethylene + Propylene Yield

• ~25% higher $C_2 = + C_3 =$ yield versus commercialized alternative
• ~5% higher $C_2 = + C_3 =$ yield than best represented alternate MTO Technology

<table>
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<tr>
<th>Section</th>
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<tbody>
<tr>
<td>Rx/Rg</td>
<td>Highest olefin production</td>
</tr>
<tr>
<td>OCP</td>
<td>High selectivity process to convert $C_4 =+$ to $C_2 =$ and $C_3 =$</td>
</tr>
<tr>
<td>OPU</td>
<td>Highest $C_2 =$ and $C_3 =$ recovery. At least 0.2% higher than alternate</td>
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~$25M* per year additional product revenue than best alternate represented

* Unit capacity = 1650kMTA MeOH

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Lowest Capital Cost

• ~12% Lower Capital Cost than alternate MTO technology

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<tr>
<td>Rx/Rg</td>
<td>Small Rx/Rg and fewest stage of product compression</td>
</tr>
<tr>
<td>OCP</td>
<td>Fixed bed reactor system</td>
</tr>
<tr>
<td>OPU</td>
<td>Single refrigeration system and no demethanizer column</td>
</tr>
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~$60M Lower CapEx

* Unit capacity = 1650kMTA MeOH
Lowest Operating Cost

- ~60% lower catalyst makeup rate
- Lower utility consumption

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<tr>
<td>Rx/Rg</td>
<td>Robust MTO catalyst, lowest catalyst makeup rate, lowest compression</td>
</tr>
<tr>
<td>OCP</td>
<td>Fixed vs fluidized reactor</td>
</tr>
<tr>
<td>OPU</td>
<td>No demethanizer column</td>
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~$6M/year lower OpEx

* Unit capacity = 1650kMTA MeOH
Highest Reliability and Unit Availability

- All sections commercially proven

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<td>Rx/Rg</td>
<td>Full combustion regenerator. No CO Boiler. Highest reliability.</td>
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<tr>
<td>Rx/Rg</td>
<td>Utilization of UOP’s extensive FCC experience with &gt;200 FCC units in operation</td>
</tr>
<tr>
<td>OCP</td>
<td>Two fixed bed reactor system vs fluidized bed.</td>
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>$2M per year more LO product through higher unit availability

* Unit capacity =1650kMTA MeOH
UOP Advanced MTO vs Alternate MTO Technology

- Comparison of project financial performance:

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<tr>
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<th>Alternate MTO</th>
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<tr>
<td><strong>Project IRR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(100% Equity)</td>
<td></td>
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<tr>
<td>2020 Intl. Expected</td>
<td>29.5%</td>
<td>21.4%</td>
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<tr>
<td>2020 Iranian Netback</td>
<td>38.8%</td>
<td>30.4%</td>
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<tr>
<td>2017 Iranian Netback</td>
<td>34.7%</td>
<td>29.4%</td>
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<tr>
<td><strong>Project IRR</strong></td>
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<tr>
<td>(70/30 Debt/Equity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020 Intl. Expected</td>
<td>24.0%</td>
<td>15.5%</td>
</tr>
<tr>
<td>2020 Iranian Netback</td>
<td>34.0%</td>
<td>24.9%</td>
</tr>
<tr>
<td>2017 Iranian Netback</td>
<td>29.5%</td>
<td>23.9%</td>
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UOP Advanced MTO technology provides the best project economics
Summary

• UOP Advanced MTO produces the highest total ethylene and propylene yield at the lowest cost.

• UOP Advanced MTO is commercially proven technology with 9 units licensed 2 of which are operating successfully with 1 currently in start-up.

• UOP Advanced MTO operating units have demonstrated stable operation that exceed guaranteed performance.

• UOP Advanced MTO technology operating units have demonstrated significant P/E ratio flexibility.

• UOP Advanced MTO provides the best project economics and the minimum project risk.