Crude oil-to-chemicals (COTC): An industry gamechanger?

Dr. Richard Charlesworth, Executive Director
Agenda

- Refinery and Petrochemicals Integration
- Overview of COTC projects
- Production Capacities & Competitiveness
- An Industry Gamechanger?
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Converging forces are forecasted to halt growth in refined products

- Annual refined product growth from 2020 to 2030 expected to be 0.6% and then plateau due to:
  - Reduced Transportation Fuel Usage
  - Substitution by NG, LPG, H2, Biofuels
  - Regulations/Taxes/Mandates

- In contrast, market forces increase petrochemical demand due to:
  - Population Growth
  - Middle Class Growth

- Therefore Refinery/Petrochemicals integration expected to grow
Refinery and petrochemical plants have achieved various degrees of integration.
Refineries must integrate to survive

2020: East-of-Suez refinery margin analysis

Source: IHS Markit

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The portion of the barrel of oil converted to petrochemical feedstocks continues to increase.

Degree of Refinery/Petrochemical Integration =

Feedstock for Petrochemical Production
Crude processing capacity of Refinery
Crude Oil to Chemicals (COTC) elevates petrochemical production to refinery scale (x4)

- COTC goes beyond such “state-of-art” refinery petrochemical integration.
- COTC reconfigures a refinery to produce **maximum chemicals** instead of fuels and thus merge refinery and petrochemical plants into one.
- Due to its large scale, COTC is an imminent threat to existing producers however it depends on the chemical chains
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Crude oil to chemical routes

- **Conventional process**
  - Crude oil → Refinery → Naphtha → Steam cracker
  - Light crude
  - Mixed crudes
  - Crude oil to PX complex → Petrochemicals

- **ExxonMobil**
  - Crude oil to PX complex → Petrochemicals
  - Light crude

- **Hengli**
  - Crude oil to PX complex → Petrochemicals
  - Mixed crudes

- **Zhejiang**
  - Crude oil to PX complex → Petrochemicals
  - Light crude

- **Shenghong**
  - Crude oil to PX complex → Petrochemicals
  - Light crude

- **Henyi**
  - Crude oil to PX complex → Petrochemicals
  - Light crude

- **Aramco/SABIC**
  - Crude oil to chemicals complex → Petrochemicals
  - Light crude
ExxonMobil’s approach to steam cracking crude oil

- Preheat crude oil in cracker furnace convection section
- Partially vaporize heated crude in flash pot outside furnace
- Flash pot overhead vapor (76%) fed to cracker furnace radiant coils
- Dispose of 24% flash pot bottoms liquid (resid) in refinery
- Implementation of this technology depends on a very light oil such as TAPIS.
- Scale is limited by steam cracker
ExxonMobil Huizhou Phase 1 Process Units

ExxonMobil Huizhou Phase 1 Process Units

Direct Crude to Steam Cracker Phase 1

$4bn Investment

Light crude e.g. Tapis

Crude desalting

1,200 KTA
Ethylene

660 KTA metallocene PE
550 KTA bimodal PE

Propylene

430 KTA high impact PP
420 KTA homo PP

C4

Butene-1, Isobutylene

Pygas

Pygas hydrogenation, Aromatics extraction

Clean Fuel Oil

Sulfur

IHS Markit
### Not all “Crude to Chemical” Projects are equal

<table>
<thead>
<tr>
<th>Project</th>
<th>Refinery Capacity (MMTPA)</th>
<th>P-Xylene Capacity (MMTPA)</th>
<th>Ethylene Capacity (MMTPA)</th>
<th>Est. Chemical conversion/ bbl. of oil (%)</th>
<th>Investment ($bn)</th>
<th>Full line Operation</th>
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</thead>
<tbody>
<tr>
<td>Hengli Petrochemical</td>
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<td>Zhejiang Petroleum and Chemical (ZPC) Phase 1</td>
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<td>Hengyi (Brunei) PMB Refinery-Petrochem</td>
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<tr>
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<td>Shenghong refinery and Integrated Petrochem</td>
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<tr>
<td>Tangshan Xuyang (Risun)***</td>
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<td>Aramco/SABIC JV</td>
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* ZPC/UOP press release Jan. 17, 2019 announced that Phase 2 configuration and technology will be changed from Phase 1.

** Based on information obtained by IHSM from a visit to Shenghong in November 2018

*** A newly announced project which is under environmental impact Assessment

+ Aramco also developing technology with Chevron Lummus Global with the aim of converting 70%+
Hengli’s Refinery-PX complex configuration

Crude Oil
20 MMTPA

60% Saudi Heavy
30% Saudi Medium
10% Marlim

Avg. API= 27.62
S= 2.26%

Key technologies supplied by Axens

Source: PEP 303
Zhejiang Petroleum Petrochemical Complex - Phase 1

Crude Oil
20 MMTPA

1:1 mix of Arabian medium and Iranian Light, or
3:7 mix of Brazilian Frade and Iranian Heavy

CDU

Light Hydrocarbon Recovery

Dry gas
LPG
Naphtha Hydrogenation

VDU

Diesel Hydrocracking 2X

CDU Residue

Diesel

CDU Residue

Light V Gasoil Hydrocracking

RFCC

Heavy naphtha

VDC Residue

Heavy V Gasoil

Coking

Coke

Kerosene

Gasoline

5.4 Mta PX

Benzene

Source: PEP 303

Key technologies supplied by Honeywell UOP
Saudi Aramco’s approach to steam cracking crude oil is olefins focused

- ARAMCO feeds Arabian Light crude oil to resid hydrocracker (HK)
- Lightest 85% of HK product conventionally steam cracked
- Heaviest 15% of HK product fed to proprietary high-severity fluid cat cracker (FCC), making cracked naphtha + propylene
- FCC technology developed as joint venture with Nippon JX.
- In addition to the Aramco/SABIC JV, Aramco announced work with Chevron Lummus Global (CLG) to develop hydrocracking technology (70-80% per barrel of oil to chemicals)
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Hengli’s Refinery-PX complex product yields

- Coal gasification
- Hydrogen
- Methanol (for MTBE)

Hengli Refinery – PX Complex

- 12 Mta Saudi heavy
- 6 Mta Saudi medium
- 2 Mta Marlim

Avg. API= 27.62
S= 2.26%

Mta = million tons per year

Total Chemicals = 8.4 Mta (42% Conversion)

- PX 4.34
- Benzene 0.97
- Naphtha 1.63
- PP 0.44
- Lube 0.54
- Acetic Acid 0.35
- Heavy Aromatics 0.13
- LPG 0.65
- Gasoline 4.61
- Kerosene 3.74
- Diesel 4.61
- Sulfur 0.52

Source: PEP 303
Comparison between PEP estimate and Hengli announcement

- **Product yields – Major products**

<table>
<thead>
<tr>
<th>Product</th>
<th>This study (KTPA)</th>
<th>Hengli announcement</th>
<th>% Deviation</th>
</tr>
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<tbody>
<tr>
<td>PX</td>
<td>4,340</td>
<td>4,340</td>
<td>0%</td>
</tr>
<tr>
<td>Benzene</td>
<td>960</td>
<td>970</td>
<td>-1.03%</td>
</tr>
<tr>
<td>Diesel</td>
<td>1,610</td>
<td>1,610</td>
<td>0%</td>
</tr>
<tr>
<td>Kerosene</td>
<td>3,540</td>
<td>3,710</td>
<td>-4.58%</td>
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<tr>
<td>Gasoline</td>
<td>4,580</td>
<td>4,610</td>
<td>-0.65%</td>
</tr>
<tr>
<td>Naphtha</td>
<td>1,500</td>
<td>1,630</td>
<td>-7.98%</td>
</tr>
<tr>
<td>LPG</td>
<td>620</td>
<td>620</td>
<td>0%</td>
</tr>
<tr>
<td>PP</td>
<td>440</td>
<td>440</td>
<td>0%</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>330</td>
<td>330</td>
<td>0%</td>
</tr>
</tbody>
</table>

- **Capex – Plant construction cost**

![Capex bar chart]

Source: PEP 303
Global paraxylene production capacity rank

- **Hengli**
Asian paraxylene market will be severely disrupted

China PX Capacity vs. Demand

China PX Imports in 2018

Total PX Imports= 15,954 Kta in 2018

Source: IHS Markit Paraxylene World Analysis
We expect the paraxylene projects to be very competitive on the global cash cost curve.
Aramco + CLG crude oil steam cracking yields

20 Mta Arabian Light Avg. API= 34

Mta= million tons per year

Aramco Crude to Chemicals Complex

Total chemical products about 14.3 Mta (72% yield)

- Ethylene 4.71
- Propylene 3.08
- C4 Fraction 2.54
- Pyrolysis Gasoline 4.00
- Gasoline (Aromatics Rich) 1.15
- Hydrogen (95%) 0.26
- Fuel Oil 1.24
- Light Cycle Oil 0.32
- Methane 2.1 (used as fuel in steam cracker)
- Sulfur 0.6

Source: PEP 29J Conceptional design based on Aramco patents
We expect the Aramco projects to be competitive on the global cash cost curve.
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Crude oil-to-chemicals (COTC): An industry gamechanger? It depends….

- Depends on Crude
  - ExxonMobil approach requires a light crude

- Depends on Product
  - COTC will be hugely disruptive to the paraxylene industry. Less so the olefins chain due to scale vs the market, number of projects and project timescale

- Depends on Raising Large Capital
  - $10-$20bn for a COTC complex means that only “major” companies can raise the necessary capital

- Depends on Location
  - ROIs will be questionable in regions of higher relative CAPEX so China has a great advantage with location factor of ≈0.6 vs. USGC
Thank you

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