Maximizing Refinery Margins by Petrochemical Integration

Presented by:
Rajeev Singh
Global Demand for Refined Products

- **2012:** Gasoline 25%, Naphtha 7%, Diesel 22%, Other Middle Distillate 25%, Heavy Fuel Oil 29%, Other 7%
- **2013:** Gasoline 29%, Naphtha 7%, Diesel 22%, Other Middle Distillate 25%, Heavy Fuel Oil 29%, Other 7%
- **2014:** Gasoline 29%, Naphtha 7%, Diesel 22%, Other Middle Distillate 25%, Heavy Fuel Oil 29%, Other 7%
- **2015:** Gasoline 29%, Naphtha 7%, Diesel 23%, Other Middle Distillate 25%, Heavy Fuel Oil 29%, Other 7%
- **2020:** Gasoline 30%, Naphtha 8%, Diesel 24%, Other Middle Distillate 25%, Heavy Fuel Oil 30%, Other 6%
- **2025:** Gasoline 30%, Naphtha 8%, Diesel 25%, Other Middle Distillate 25%, Heavy Fuel Oil 30%, Other 4%
- **2016-2025 Incremental:** Gasoline 7%, Naphtha 4%, Diesel 17%, Other Middle Distillate 29%, Heavy Fuel Oil 29%, Other 4%

Reduced Gasoline & Naphtha demand

Source: Hart Energy Research & Consulting
Regional Gasoline Growth

- Regional Imbalance in Gasoline Production and Demand
- Increased percentage of “renewables” (EthOH) in Gasoline pool displaces some refined gasoline

Export Naphtha or Upgrade?

Source: Hart Energy Research & Consulting
Tightening Fuel Specifications

Global Gasoline Demand (by S Spec)

Tighter Sulfur Specs in Fuel
- Limits naphtha blending into gasoline pool
- Desulfurization → loss of Olefins & Octane value
  costly, CAPEX and OPEX

Upgrade Instead to Petrochemicals!

Source: Hart Energy Research & Consulting
Refinery Trends: India

• Implementation of BS IV in India From April 2017.

• Gasoline Specification gets stringent to meet BS IV Standards.

• In rural areas, a shift in Gas for cooking and electricity for lighting has resulted in decrease in Kerosene Demand.

• There are 23 refineries spread across in India with refining Capacity of 230 MTPA.

Surplus Naphtha & Kerosene ?
Petrochemicals Outlook

WORLD LIGHT OLEFINS DEMAND

World Light Olefins Demand

- Propylene
- Ethylene

WORLD OLEFINS DEMAND BY REGION

World Olefins Demand by Region

Source: Hart Energy Research & Consulting
Benefits of Refinery Petrochemical Integration

> Assured Refinery product uptake
> Secure Petrochemical Feedstock availability
> Significant savings in investment
  - Shared utilities, infrastructure, logistics
> Savings in operating costs
  - Energy integration, Shared Resources
> FeedStock & Product Flexibility to Meet market Demand
> Improved Gross Refinery Margin (GRM)
# KBR Olefins Technology Portfolio

<table>
<thead>
<tr>
<th>What</th>
<th>Feeds</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCORE™</strong> <em>(Steam Cracking)</em></td>
<td>Ethane through Gas Oil</td>
<td>• Residence time ~0.08 – 1.0 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low CAPEX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Superior Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Offered via Agreement with ExxonMobil</td>
</tr>
<tr>
<td><strong>Off Gas Recovery</strong></td>
<td>Low value refinery Off gases</td>
<td>• Recovers Most of Ethylene &amp; Propylene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recovers Paraffins (Ethane &amp; Propane ) in recycle Stream</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low Capital Cost &amp; Low Energy Consumption</td>
</tr>
<tr>
<td><strong>K-COT™</strong> <em>(Catalytic Olefins)</em></td>
<td>Olefinic C4-C10</td>
<td>• P/E ratio ~ 2/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gasoline by-product &gt;50% aromatics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recycle C4-C6 NA to extinction without additional treating</td>
</tr>
<tr>
<td></td>
<td>Paraffinic naphtha, light distillates</td>
<td>• P/E ratio ~ 1/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recycle C4s/C5s without additional treating</td>
</tr>
<tr>
<td></td>
<td>Non-traditional</td>
<td>• High olefin yields from methanol, ethanol and other oxygenates and MTO/MTP and FT by-products</td>
</tr>
</tbody>
</table>
### SCORE™

<table>
<thead>
<tr>
<th>What</th>
<th>Feeds</th>
<th>Features</th>
</tr>
</thead>
</table>
| SCORE™ (Steam Cracking) | Ethane through Gas Oil | • Residence time ~0.08 – 1.0 sec  
• Low CAPEX  
• Superior Performance  
• Offered via Agreement with ExxonMobil |
| Off Gas Recovery | Low value refinery Off gases | • Recovers Most of Ethylene & Propylene  
• Recovers Paraffins (Ethane & Propane ) in recycle Stream  
• Low Capital Cost & Low Energy Consumption |
| K-COT™ (Catalytic Olefins) | Olefinic C4-C10 | • P/E ratio ~ 2/1  
• Gasoline by-product >50% aromatics  
• Recycle C4-C6 NA to extinction without additional treating |
| | Paraffinic naphtha, light distillates | • P/E ratio ~ 1/1  
• Recycle C4s/C5s without additional treating |
| | Non-traditional | • High olefin yields from methanol, ethanol and other oxygenates and MTO/MTP and FT by-products |
Introduction to SCORE™

SCORE™, is the traditional steam cracker technology offered in collaboration with ExxonMobil that combines Selective Cracking furnace technology with an Optimum REcovery section.
## SCORE™ Furnace Portfolio

<table>
<thead>
<tr>
<th>Coil Type</th>
<th>One pass</th>
<th>Two pass</th>
<th>Four pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residence Time (sec)</td>
<td>0.1</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>SCORE</td>
<td>SC-1</td>
<td>SC-2</td>
<td>SC-4</td>
</tr>
<tr>
<td>Competitors</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Coil Type Diagrams:**
- **SC-1**: Single Pass Straight Tube (~ 0.08 - 0.12 sec)
- **SC-2**: Two-Pass (~ 0.18 - 0.25 sec)
- **SC-4**: Serpentine-Type (~ 0.35-1.0 sec)

**Furnace Coil Portfolio**

- **Highest Ethylene Yield In Industry**

**Broadest range of residence times in the Industry**
### SCORE™ Furnace Flexibility

#### Multi-Feed (Hybrid) Cracking

<table>
<thead>
<tr>
<th>SCORE™ Furnaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large Capacity</td>
</tr>
<tr>
<td>• Single Cabin Firebox</td>
</tr>
<tr>
<td>• 8 individually flow controlled passes</td>
</tr>
<tr>
<td>• Number of Feeds only limited by inlet piping arrangement</td>
</tr>
<tr>
<td>• Each Feed can be cracked at optimum conditions:</td>
</tr>
<tr>
<td>- Temperature</td>
</tr>
<tr>
<td>- S:HC Ratio</td>
</tr>
</tbody>
</table>

#### Furnace Flexibility of 8 Mini Furnaces within a Single Firebox

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
Petrochemical Feedstock Flexibility

Flexibility to Crack range of feed

- LPG
- Naphtha
- Light Distillate
- Heavy Distillate
- Off Gas From FCC & DCU
- Propane
- Butane
- Straight Run
- Paraffinic
- Kerosene
- Gas Oil
- Ethane & Propane
- Ethylene & Propylene

Traditional Feedstock
Non-Traditional Feedstock
Recent Trend in Feedstock

Refinery

SCORE
SCORE™ Reference Facility

Configuration
- Four (4) Hydrocarbon Furnace Feeds
- Furnaces 1 – 3: 50/50 Flexibility
- Furnaces 4 – 5: Full Flexibility
- Total No. Cracking Cells: 
  \[ (3 \times 2) + (2 \times 8) = 22 \]

Advantages
- No Dedicated Recycle Gas Furnace
- No Co-Cracking:
  - Feeds cracked at optimum conditions
- High Flexibility
- Low TIC

Flexibility allows Maximum Profitability
# Off Gas Recovery Unit Technology

<table>
<thead>
<tr>
<th>What</th>
<th>Feeds</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCORE™ (Steam Cracking)</td>
<td>Ethane through Gas Oil</td>
<td>• Residence time ~0.08 – 1.0 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low CAPEX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Superior Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Offered via Agreement with ExxonMobil</td>
</tr>
<tr>
<td>Off Gas Recovery</td>
<td>Low value refinery Off gases</td>
<td>• Recovers Most of Ethylene &amp; Propylene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recovers Paraffins (Ethane &amp; Propane ) in recycle Stream</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low Capital Cost &amp; Low Energy Consumption</td>
</tr>
<tr>
<td>K-COT™ (Catalytic Olefins)</td>
<td>Olefinic C4-C10</td>
<td>• P/E ratio ~ 2/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gasoline by-product &gt;50% aromatics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recycle C4-C6 NA to extinction without additional treating</td>
</tr>
<tr>
<td></td>
<td>Paraffinic naphtha, light distillates</td>
<td>• P/E ratio ~ 1/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recycle C4s/C5s without additional treating</td>
</tr>
<tr>
<td></td>
<td>Non-traditional</td>
<td>• High olefin yields from methanol, ethanol and other oxygenates and MTO/MTP and FT by-products</td>
</tr>
</tbody>
</table>
Off Gas Recovery Unit – Introduction

Off Gas Stream Rich in High Value Olefins

Refinery Off Gas - Rich in Olefins, C2 & C3 saturates, normally used as fuel gas.

KBR Provides solution to recover – high value olefins, C2 & C3 saturates and fuel gas products with - Off Gas Recovery Technology.
Off Gas Recovery Unit – Overview

**PROCESS BLOCK**

- **STANDALONE**
  - CONTAMINANT REMOVAL
  - RECOVERY SECTION
    - PG ETHYLENE, ETHANE, C3 PRODUCT
    - HIGH HEATING VALUE FUEL GAS

- **INTEGRATED**
  - CONTAMINANT REMOVAL
  - REFINERY GAS RECTIFIER
    - PRODUCT: FUEL GAS AND C2+ RICH STREAM
      - INTEGRATED WITH STEAM CRACKER

**UTILITIES AND ANCILLARIES BLOCK**

- **STANDALONE**
  - PROPYLENE REFRIGERANT
  - CW, STEAM, ELECTRICITY
    - (CAN BE INTEGRATED WITH REFINERY)

- **INTEGRATED**
  - SAME AS STEAM CRACKER
    - (PR & ER REFRIGERATION, CW, STEAM, ELECTRICITY)
## KCOT™

<table>
<thead>
<tr>
<th>What</th>
<th>Feeds</th>
<th>Features</th>
</tr>
</thead>
</table>
| **SCORE™**<br>(Steam Cracking) | Ethane through Gas Oil | • Residence time ~0.08 – 1.0 sec  
• Low CAPEX  
• Superior Performance  
• Offered via Agreement with ExxonMobil |
| **Off Gas Recovery** | Low value refinery Off gases | • Recovers Most of Ethylene & Propylene  
• Recovers Paraffins (Ethane & Propane) in recycle Stream  
• Low Capital Cost & Low Energy Consumption |
| **K-COT™**<br>(Catalytic Olefins) | Olefinic C4-C10 | • P/E ratio ~ 2/1  
• Gasoline by-product >50% aromatics  
• Recycle C4-C6 NA to extinction without additional treating |
|  | Paraffinic naphtha, light distillates | • P/E ratio ~ 1/1  
• Recycle C4s/C5s without additional treating |
|  | Non-traditional | • High olefin yields from methanol, ethanol and other oxygenates and MTO/MTP and FT by-products |
Introduction to K-COT™

K-COT™ is KBR’s Catalytic Olefins Cracking Technology (FCC) that processes light Olefinic, Paraffinic or mixed feeds, resulting in high propylene yields with ethylene and aromatic-rich gasoline by-products.
Reactor Converter

• Proven FCC-based technology
• Tailored catalyst maximizes propylene yield
• Smooth Startup
• Simple operation
• Low maintenance
• Wide Feed flexibility
Traditional Integration Scheme

- Crude Oil
- CDU
- FCC
- Isom
- Hydrotreaters
- De-asphalters
- Coker
- Others
- Gasoline
- Distillate
- Jet / Kero
- Fuel Oil
- Ethylene
- Propylene
- Butadiene
- PyGas
- Hot Section
- Cold Section
- Off Gas Recovery
- Off Gases
- Ethane
- Propane
- LPG
- Naphtha

Theme: The Age of Downstream Transformation

25 & 26 MAY 2017, BEC, MUMBAI, INDIA
Optimized Integration Scheme

- Crude Oil
- FCC
- Isom
- Hydrotreaters
- CDU
- De-asphalting
- Coker
- Others
- Gasoline
- Distillate
- Jet / Kero
- Fuel Oil

Off Gases

- Off Gas Recovery
- Ethane
- Propane
- Ethylene
- Propylene

Hot Section

- Naphtha
- LPG

Cold Section

- Catalytic Olefins

Recovery

- Ethylene
- Propylene
- Butadiene
- PyGas

Theme: The Age of Downstream Transformation
Typical Ultimate Yields from KCOT™ Unit

Paraffinic Feed

- Steam Cracker
- Catalytic Olefins

Olefinic Feed

- C4 Raff-1
- C5s
- FCC LN
- Coker LN

- Others
- Hvy Gasoline
- Propylene
- Ethylene

Steam
Cracker
Catalytic
Olefins

Other
Gasoline
Propylene
Ethylene

Paraffinic Feed

Olefinic Feed
Conclusion

• Global trend reflects decrease in demand for Gasoline & Naphtha.

• Petrochemicals show incremental Growth across the world.

• Market volatility & Sustainability demands Integration of Refinery with Petrochemicals.

• KBR Offers technology with unmatched Feed & Product Flexibility to meet market demand.

• Higher Flexibility Offers Higher Profit Margin for Refineries.