Opportunities & Challenges in Transportation Fuels Production

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Outline

- Crude Oil & Bitumen
  - Availability
  - Upgrading and refining
- Gasoline
  - Low sulfur gasoline
  - Ethanol blending
  - Gasoline benzene
- Diesel
  - ULSD
  - Biodiesel
US Energy Long Term Challenges

• Conventional Crude oil
  – Crude oil quality is declining
  – Increased competition – China & India
  – Oil companies and national oil suppliers relationships are evolving
  – Supply disruptions are more frequent
• Crude oil consumption is expected to increase
• Greenhouse gas emissions and climate issues are ratcheting up
Global Oil Reserves By Country (Source: CAPP)

Canada, with 173 billion barrels in oil sands reserves, ranks 2nd only to Saudi Arabia in global oil reserves.

Ref: Emerging technologies for producing paraffins, olefins & aromatics, Michael C. Oballa & Vasily Simanzhenkov
Oils Sands: A mixture of sand, crude bitumen, water and clay

**Typical Composition**
- 10% bitumen
- 83% sand
- 7% water & clay

- 1 barrel of bitumen is obtainable from 3 to 4 tons of oil sands!
- Bitumen is an extra heavy, sour, poor quality oil
- Significant upgrading required
- 10% higher GHG generated relative to conventional oil?
Non Facile Commercial Recovery Technologies

Surface Mining

Steam Assisted Recovery

Steam Assisted Gravity Drainage (SAGD)-Schematic

- horizontal drilling
- Moderate pressure steam (500 psi)
- 50% - 70% oil in place recovery

Courtesy EnCana
Bitumen Pose Significant Challenges

- Bitumen and fractions have higher contaminants
  - Sulfur distributions reflect more refractory compounds
  - Higher refractory nitrogen
  - Higher TAN (Athabasca 3.5 relative to < 1 for conventional oils)
- Significantly higher hydrogen consumption
- Natural gas dependency for fuel and hydrogen
- High requirement for naphtha
- Pipeline infrastructure for market accessibility
- Environmental issues
  - Land reclamation
  - Sour gases and GHG
  - Water conservation

Plant flexibility and operating margins could be impacted.
## Bitumen Refining Challenges

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Arab Med(^{(1)})</th>
<th>Mars</th>
<th>Maya</th>
<th>Hamaca Bitumen(^{(2)})</th>
<th>Athabasca Bitumen(^{(3)})</th>
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<tbody>
<tr>
<td>Gravity, API</td>
<td>30.7</td>
<td>28.1</td>
<td>20.9</td>
<td>8.4</td>
<td>7.5</td>
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<tr>
<td>Sulfur, wt. %</td>
<td>2.4</td>
<td>2.2</td>
<td>3.4</td>
<td>3.8</td>
<td>4.8</td>
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<tr>
<td>TAN, mg/g</td>
<td>0.25</td>
<td>0.63</td>
<td>0.32</td>
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<td>Ni, wppm</td>
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<td>20</td>
<td>52</td>
<td>115</td>
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<td>V, wppm</td>
<td>18</td>
<td>46</td>
<td>232</td>
<td>388</td>
<td>290</td>
</tr>
</tbody>
</table>

1. Marathon crude oil assay database
A Typical Bitumen Upgrader

Naphtha-Jet Distillates

N-J HDT

Distillate HDT

SCO to Refinery

Atmospheric Distillation Unit

Vacuum Distillation Unit

Vacuum Residue

Diluent Recycled

Bitumen

Diluent

Naphtha-Jet

Distillates

LVGO

HVGO

Vacuum Gas Oil to Refinery

off gases

SCO to Refinery

Diluent

A Typical Bitumen Upgrader
A Simplified Refinery Flow Diagram

- Crude Oil
- Atm Unit
- NHT
- LSR H/T
- Catalytic Reformer
- Penex
- Gasoline Blending
- DHT
- Distillate Fuels
- H/C
- GDU
- Coke
- Asphalt
- Vac Unit
- Coker Unit
Crack Spread Declining
## 2009 Market Indicators Are Lower

<table>
<thead>
<tr>
<th></th>
<th>2008 2Q</th>
<th>2009 2Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago LLS 6-3-2-1 ($/BBL)</td>
<td>2.71</td>
<td>5.73</td>
</tr>
<tr>
<td>Sweet/Sour Diff. ($/BBL)</td>
<td>13.74</td>
<td>3.98</td>
</tr>
<tr>
<td>NYMEX WTI ($/BBL)</td>
<td>123.80</td>
<td>59.80</td>
</tr>
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</table>
US Refiners Produce Low Sulfur Gasoline

• 2006 gasoline sulfur regulation of < 30 wppm S  
  – US refiners met regulation using a variety of technologies and hydrotreating catalysts
• Optimized gasoline desulfurization to preserve octane
• Technologies used included
  – Axens Prime G
  – CD Tech
  – ConocoPhillips Szorb
  – ExxonMobil Scanfining
• Pool gasoline octane losses of 1 to 3 numbers
Ethanol Blending & Naphtha Reforming

• US goal is 35 billion gallons per year of ethanol in gasoline by 2022
• E10 gasoline lead to
  – Increased gasoline volume
  – **Gasoline octane giveaway**
  – Low severity reformer operations
  – Lower hydrogen production
  – Inefficient catalytic reformer productivity
• Maximize gasoline octane barrels and hydrogen
• Energy savings negligible relative to losses of $H_2$ and reformate
• Key benefits are less utilization of crude oil for gasoline and enhanced environmental quality
US EPA Gasoline Benzene Regulation

- **US EPA Mobile Source Air Toxics II (MSAT II) regulations effective Jan 2011**
  - Annual corporate average gasoline pool benzene of 0.62 vol. %
  - Credits and trade arrangements possible
  - By July 2012, maximum refinery average gasoline benzene of 1.3 vol. %

- **Catalytic Reformers produce over 80 % of gasoline benzene**

- **Naphtha Pre-fractionation and Post-fractionation**

- **Pre-fractionation employs naphtha split to reduce benzene and precursors to the reformer**
  - Naphtha Splitter at the crude unit or after NHT
  - Benzene and precursors converted via Bensat and C5/C6 isomerization
  - Achieved ~ 35 to 50 % drop in gasoline benzene at two Marathon refineries

- **Gasoline benzene credits option**
US EPA Gasoline Benzene Regulation

- Post-fractionation and gasoline benzene minimization processes
  - Extractive distillation for benzene
    - UOP, Uhde
    - Reduced gasoline volume
    - Octane impact
  - Benzene saturation
    - Axens, UOP
    - Gasoline volume maintained
    - Impact on Octane & H2 consumption
  - Benzene alkylation to cumene
- Capital intensive processes for reducing gasoline benzene and maximizing hydrogen production
N. American Clean Diesel Growth Through 2018

Source: Hart World Refining & Fuels Service
Oil Refiners Met ULSD Regulation

- Technology and oil refining companies honed in on refractory sulfur compounds including 4,6 DM DBT

\[
\text{CH}_3 \quad \text{S} \quad \text{H}_3\text{C} \quad \text{CH}_3
\]

- Utilized a combination of new hydrotreating catalysts, increased reactor volumes, reactor internals process modifications
  - Grassroots Units (~15%)
  - Unit Revamps (~75%)
  - No modifications (~10%)

- Oil refiners achieved < 10 wppm sulfur to meet pipeline requirements
Renewable Diesel Fuels Information

- The mandate for annual renewable fuels use is 36 billion gallons of biofuels by 2022
- Biodiesel is a renewable fuel for diesel engines
  - from natural oils -- soybean oil via reaction with methanol
  - comprised of mono-alkyl esters of long fatty acids
  - meets specifications of ASTM D6751\(^1\)
  - pure biodiesel is B100
- Biodiesel blend is a blend of biodiesel fuel with petroleum based diesel fuel
  - BXX, where XX represents percentage of biodiesel
  - B2, B5 and B20 are used

Ref: Biodiesel Technical Information, ADM Biodiesel Technical Services
US Biodiesel Production On the Rise

- B20 emissions are lower than conventional diesel
  - 21% lower HCs
  - 11% lower CO
  - 20% lower PMs
  - ~5% + NOx
  - 20% lower PAH

Ref: Clean Cities Fact Sheet US DOE Apr. 2008

US Biodiesel Production

Ref: Clean Cities Fact Sheet US DOE Apr. 2008
Biofuels Use Will Increase Substantially

Source: Hart World Refining & Fuels Service
Summary

• Unconventional oils will have a significant impact on US refining plants reliability and profitability
• Cost of meeting environmental regulations and GHG rebitumen production will be a factor
• Ethanol gasoline and benzene will challenge US refiners
• Diesel growth is expected worldwide relative to gasoline
• Biofuels use would increase significantly in the next 15 years
The Future -- Gas to Liquids?
## Upgraded Bitumen Still Challenging

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<th>WCS&lt;sup&gt;(4)&lt;/sup&gt;</th>
<th>Athabasca Bitumen&lt;sup&gt;(3)&lt;/sup&gt;</th>
<th>Muskeg R. Bitumen&lt;sup&gt;(3)&lt;/sup&gt;</th>
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1. Marathon crude oil assay database
4. WCS is Western Canadian Select