Bitumen Partial & Targeted Upgrading: the Next Step

CALGARY, ALBERTA, CANADA

Organized by: WHOC15-206
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Introduction

• What is next step for Alberta Bitumen?

• Status of Current Partial Upgrading concepts

• FTCrude® Partial Upgrading Concept

• Saskatchewan Research Council (SRC) PUB Pilot Work

• Targeted PUB blends and related economics

• Conclusions and Observations
Alberta Bitumen Issues

• Bitumen relies on the addition of diluent for transporting
  – DilBit/SynBit is costly
  – Diluent recovery and recycling is costly
  – Limited Diluent availability

• Lack of pipeline capacity and low pipeline efficiency using high diluent content

• Environmentally undesirable components of heavy metals, sulfur, olefins and petcoke

• Incompatible feedstock for existing refineries
Will New Bitumen Upgraders be in Alberta Future?

- **Economic Drivers needed for new Upgrader projects:**
  - SCO price premium over WTI (5 to 10%)
  - High light-heavy crude cost differentials (>\$25/bbl)

- **Current Economic Concerns:**
  - Current light-heavy price differentials ($12 to $15/bbl)
  - Rising capital cost for Alberta based new upgrading or refining
  - Government regulations for a higher carbon tax

- **Conclusion:**
  - Alberta’s economic environment is not conducive to building new grass roots Upgraders / Refineries
Partial or Targeted Upgrading

OBJECTIVES

• The basic partial upgrading process is designed to meet pipeline specifications for gravity (>19°API) and viscosity (<350 cSt at 15°C) – to reduce or eliminate the addition of diluent

• Removes/reduces major impurities such as sulfur, micro-carbon, heavy metals and acidity

• Produces a crude oil quality compatible with current desirable refinery feed requirements

• Significantly reduce CAPEX and OPEX costs compared to full upgrading or refining in Alberta
Current Partial Upgrader Technologies

• Several technologies are at various stages of development

• Most are based on thermal cracking of some fraction of the bitumen or removal of asphaltenes:
  • Resulting in volumetric losses (10 to 30%) through waste products (asphaltenes or petcoke)
  • Thermally cracked materials tend to be unstable (solids formation) & contain olefins
## Current Partial Upgrading Technologies

<table>
<thead>
<tr>
<th>Process</th>
<th>CCU</th>
<th>HTL</th>
<th>Value Creation</th>
<th>ROSE</th>
<th>HI-Q</th>
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<tbody>
<tr>
<td>Licensor</td>
<td>UOP</td>
<td>Ivanhoe</td>
<td>Value Creation</td>
<td>KBR</td>
<td>MEG</td>
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<tr>
<td>Process Steps</td>
<td>SDA + RFCC</td>
<td>Pyrolysis + Coking</td>
<td>SDA + Coking</td>
<td>SDA</td>
<td>Thermo-cracking + SDA</td>
</tr>
<tr>
<td>Byproducts</td>
<td>Asphaltene + Coke</td>
<td>Coke</td>
<td>Asphaltene + Coke</td>
<td>Asphaltene</td>
<td>Asphaltene</td>
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<tr>
<td>Est SCO Yield (Vol%)</td>
<td>75-80</td>
<td>75-85</td>
<td>75-85</td>
<td>65-85</td>
<td>75-85</td>
</tr>
</tbody>
</table>
FTCrude® Partial and Targeted Upgrading Concept
FTCrude® Partial Upgrader Pilot Work

• SRC study (2014) confirmed the validity of FTCrude® PUB concept

• Pilot Processing Steps:
  – Feed samples of DilBit (14.7 °API) and F-T liquids
  – DilBit distilled to recover diluent and obtain Straight Run Distillate (SRD) and Atmospheric Residue (AR)
  – AR was subjected to batch solvent deasphalting to produce asphaltenes and Deasphalted Oil (DAO)
  – Basic PUB blends produced from combinations of F-T liquids with DAO and SRD
  – Targeted blends produced for transport by rail or marine
    • 14-16 °API blend of deasphalted bitumen, DilBit, SRD and Diluent
## Partial Upgraded Crude (PUB) Test Results

<table>
<thead>
<tr>
<th>BLEND</th>
<th>Components (wt%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dilbit as Received</td>
<td>Pipeline Dilbit</td>
<td>PUB 1 Blend</td>
<td>PUB 2 Blend</td>
<td>Rail / Marine Blend</td>
</tr>
<tr>
<td>Deasphalted Oil</td>
<td>46.9</td>
<td>43.9</td>
<td>26.9</td>
<td>48.2</td>
<td></td>
</tr>
<tr>
<td>Straight run Distillate</td>
<td>21.6</td>
<td>21.4</td>
<td>12.5</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td>FT Sample</td>
<td>31.5</td>
<td>34.6</td>
<td>18.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diluent (additional)</td>
<td>17.5</td>
<td>18</td>
<td></td>
<td></td>
<td>29.7</td>
</tr>
<tr>
<td>Raw Bitumen</td>
<td>82.5</td>
<td></td>
<td></td>
<td></td>
<td>42.6</td>
</tr>
<tr>
<td>Dilbit</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

### Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>PUB 1 Blend</th>
<th>PUB 2 Blend</th>
<th>Rail / Marine Blend</th>
<th>Deasphalted Dilbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity cP at 10°C</td>
<td>11,600</td>
<td>338</td>
<td>383</td>
<td>225</td>
</tr>
<tr>
<td>Viscosity cP at 30°C</td>
<td>1,740</td>
<td>102</td>
<td>122</td>
<td>68</td>
</tr>
<tr>
<td>Density kg/m³ at 10°C</td>
<td>967.9</td>
<td>928</td>
<td>921.8</td>
<td>910</td>
</tr>
<tr>
<td>API Gravity</td>
<td>14.7</td>
<td>20.9</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Sulfur</td>
<td>4.70%</td>
<td>3.87%</td>
<td>3.19%</td>
<td>2.92%</td>
</tr>
<tr>
<td>Asphaltenes (c5 Solvent)</td>
<td>18.30%</td>
<td>16.60%</td>
<td>5.66%</td>
<td>4.74%</td>
</tr>
<tr>
<td>Microcarbon (w/w)</td>
<td>12.90%</td>
<td>11.42%</td>
<td>6.01%</td>
<td>6.23%</td>
</tr>
<tr>
<td>Nickel (mg/kg)</td>
<td>73</td>
<td>63</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>Vanadium (mg/kg)</td>
<td>190</td>
<td>170</td>
<td>78</td>
<td>75</td>
</tr>
</tbody>
</table>

### Distillation (°F)

<table>
<thead>
<tr>
<th>Property</th>
<th>PUB 1 Blend</th>
<th>PUB 2 Blend</th>
<th>Rail / Marine Blend</th>
<th>Deasphalted Dilbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBP</td>
<td>36</td>
<td>1</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>50%</td>
<td>557</td>
<td>443</td>
<td>420</td>
<td>398</td>
</tr>
<tr>
<td>80%</td>
<td>n/a</td>
<td>608</td>
<td>588</td>
<td>577</td>
</tr>
<tr>
<td>FBP</td>
<td>n/a</td>
<td>741</td>
<td>738</td>
<td>738</td>
</tr>
</tbody>
</table>
# Volume Fractions of PUB Blends

<table>
<thead>
<tr>
<th>FT Crude® Partial Upgrader 100,000 bpd bitumen</th>
<th>Dilbit as Received</th>
<th>Pipeline Dilbit</th>
<th>PUB 1 Blend</th>
<th>PUB 2 Blend</th>
<th>Rail/Marine Blend</th>
<th>Deasphalted Bitumen Dilbit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blend Density (API)</strong></td>
<td>14.7</td>
<td>20.9</td>
<td>22.0</td>
<td>24.0</td>
<td>14.3</td>
<td>18.0</td>
</tr>
<tr>
<td><strong>Components (bpd)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deasphalted Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight Run Distillate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT Sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diluent (additional)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>100,000</td>
<td>100,000</td>
<td></td>
<td></td>
<td>44,377</td>
<td></td>
</tr>
<tr>
<td>Diluent (as received)</td>
<td>29,200</td>
<td>29,200</td>
<td></td>
<td></td>
<td>29,200</td>
<td></td>
</tr>
<tr>
<td><strong>Total Product</strong></td>
<td>129,200</td>
<td>165,853</td>
<td>121,381</td>
<td>123,814</td>
<td>111,892</td>
<td>112,720</td>
</tr>
<tr>
<td><strong>Diluent</strong></td>
<td>29,200</td>
<td>65,853</td>
<td>NONE</td>
<td>NONE</td>
<td>NONE</td>
<td>37,303</td>
</tr>
<tr>
<td><strong>Vol % Diluent</strong></td>
<td>22.6%</td>
<td>39.7%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>33.1%</td>
</tr>
</tbody>
</table>
# PUB Blends - Feeds & Products

<table>
<thead>
<tr>
<th>100,000 bpd Bitumen Feed-FTCrude® Partial Upgrader</th>
<th>Dilbit as Received</th>
<th>Pipeline Dilbit</th>
<th>PUB 1 Blend</th>
<th>PUB 2 Blend</th>
<th>Marine/Rail Blend</th>
<th>Deasphalted Bitumen Dilbit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feed (bpd)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Diluent</td>
<td>29,200</td>
<td>65,853</td>
<td></td>
<td></td>
<td></td>
<td>37,303</td>
</tr>
<tr>
<td>Natural Gas (mmscfd)</td>
<td></td>
<td></td>
<td>220</td>
<td>250</td>
<td>122</td>
<td>220</td>
</tr>
<tr>
<td><strong>Products (bpd)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilbit (max 350 cSt at 15°C)</td>
<td></td>
<td></td>
<td>165,853</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA Bitumen/Diluent (20°API)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>112,720</td>
</tr>
<tr>
<td>PUB (max 350 cSt at 15°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>121,381 123,814</td>
</tr>
<tr>
<td>Marine/Rail Blend (14-16°API)</td>
<td>129,200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>111,893</td>
</tr>
<tr>
<td>Separate FT Product - SynDiesel®</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45,964</td>
</tr>
<tr>
<td><strong>Total Products</strong></td>
<td>129,200</td>
<td>165,853</td>
<td>121,381</td>
<td>123,814</td>
<td>111,893</td>
<td>158,684</td>
</tr>
<tr>
<td>Product Yield to Bitumen (%)</td>
<td>129%</td>
<td>166%</td>
<td>121%</td>
<td>124%</td>
<td>112%</td>
<td>121%</td>
</tr>
</tbody>
</table>
Typical Crude Oil Assays

- **WTI**
  - Naphtha: 39.6%
  - Distillate: 0.49%
  - VGO: 45%
  - Vac Residue: 38
  - API: <50
  - % Sulfur: 3.0
  - Cetane: >21

- **Alaska North Slope**
  - Naphtha: 32%
  - Distillate: 0.9%
  - VGO: 52%
  - Vac Residue: 38
  - API: <50
  - % Sulfur: 3.4
  - Cetane: >21

- **Arabian Medium**
  - Naphtha: 30.3%
  - Distillate: 2.57%
  - VGO: 52
  - Vac Residue: 32
  - API: >50
  - % Sulfur: 4.3
  - Cetane: >21

- **SRC P/L DilBit**
  - Naphtha: 19.4%
  - Distillate: 3.9%
  - VGO: -
  - Vac Residue: -
  - API: >50
  - % Sulfur: -
  - Cetane: >21

- **SRC PUB**
  - Naphtha: 21%
  - Distillate: 3.0%
  - VGO: >50
  - Vac Residue: -
  - API: 15
  - % Sulfur: -
  - Cetane: >21

- **SRC Rail/Marine**
  - Naphtha: 15%
  - Distillate: 4.3%
  - VGO: -
  - Vac Residue: -
  - API: 19
  - % Sulfur: -
  - Cetane: >21

- **SRC Deasphalted Bitumen + Diluent**
  - Naphtha: 19%
  - Distillate: 3.4%
  - VGO: -
  - Vac Residue: -
  - API: 19
  - % Sulfur: -
  - Cetane: >21
## Commodity Pricing Assumptions

<table>
<thead>
<tr>
<th>Current Commodity Prices ($US)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WTI</strong></td>
<td>$ 50.00 per BBL</td>
<td>25% Discount WTI</td>
</tr>
<tr>
<td><strong>WCS Dilbit</strong></td>
<td>$ 37.50 per BBL</td>
<td>60% Discount WTI</td>
</tr>
<tr>
<td><strong>Bitumen</strong></td>
<td>$ 20.00 per BBL</td>
<td>10% Discount WTI</td>
</tr>
<tr>
<td><strong>Diluent</strong></td>
<td>$ 45.00 per BBL</td>
<td>10% Premium WCS</td>
</tr>
<tr>
<td><strong>FTCrude® PUB</strong></td>
<td>$ 41.25 per BBL</td>
<td>5% Premium WCS</td>
</tr>
<tr>
<td><strong>Deasphalted Dilbit</strong></td>
<td>$ 39.38 per BBL</td>
<td>5% Discount WCS</td>
</tr>
<tr>
<td><strong>Marine/Rail Blend</strong></td>
<td>$ 35.63 per BBL</td>
<td>20% Discount WCS</td>
</tr>
<tr>
<td><strong>Dilbit Received</strong></td>
<td>$ 30.00 per BBL</td>
<td>90% Premium WTI</td>
</tr>
<tr>
<td><strong>Syndiesel®</strong></td>
<td>$ 0.60 per Litre</td>
<td></td>
</tr>
<tr>
<td><strong>Natural Gas</strong></td>
<td>$ 3.00 $/MMBTU</td>
<td></td>
</tr>
<tr>
<td>FT Crude® Partial Upgrader 100,000 bpd bitumen</td>
<td>PUB 1 Blend</td>
<td>PUB 2 Blend</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>Input Cost ($/day)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>$ 2,000,000</td>
<td>$ 2,000,000</td>
</tr>
<tr>
<td>Diluent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$ 660,000</td>
<td>$ 750,000</td>
</tr>
<tr>
<td>Oxygen Cost @ $50/MT</td>
<td>$ 110,000</td>
<td>$ 110,000</td>
</tr>
<tr>
<td>Fixed Opex @4% CAPEX</td>
<td>$ 315,152</td>
<td>$ 315,152</td>
</tr>
<tr>
<td><strong>Total Feed ($/day)</strong></td>
<td>$ 3,085,152</td>
<td>$ 3,175,152</td>
</tr>
<tr>
<td><strong>Products ($/day)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dilbit (max. 350 cSt @ 15°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA Bitumen/Diluent (20°API)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUB (max 350 cSt @ 15°C)</td>
<td>$ 5,006,966</td>
<td>$ 5,107,328</td>
</tr>
<tr>
<td>Rail/Ship Blend (14-16°API)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT SynDiesel® Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Products ($/day)</strong></td>
<td>$ 5,006,966</td>
<td>$ 5,107,328</td>
</tr>
<tr>
<td><strong>Added Value ($/day)</strong></td>
<td>$ 1,921,815</td>
<td>$ 1,932,176</td>
</tr>
<tr>
<td><strong>ANNUALIZED (330 days)</strong></td>
<td>$ 634,000,000</td>
<td>$ 638,000,000</td>
</tr>
<tr>
<td><strong>Transport Tariff ($5.00/BBL)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Est. Shipping Cost ($/day)</td>
<td>$ 606,905</td>
<td>$ 619,070</td>
</tr>
<tr>
<td>Annualized</td>
<td>$ 200,278,650</td>
<td>$ 204,293,100</td>
</tr>
<tr>
<td>Est. CAPEX</td>
<td>$2,600,000,000</td>
<td>$2,600,000,000</td>
</tr>
<tr>
<td><strong>Project Unlevered IRR</strong></td>
<td>20%</td>
<td>20.1%</td>
</tr>
<tr>
<td><strong>Return NPV @ 15%</strong></td>
<td>$871,000,000</td>
<td>$892,000,000</td>
</tr>
</tbody>
</table>
Alberta SAGD Integrated Solution

- Diluent (80% to 100% Less)
- SAGD Site Partial Upgrader
- SAGD Site Partial Upgrader
- SAGD Site Partial Upgrader
- Edmonton FTCrude® Bottoms Refinery
- Export Markets
- Alberta Markets
- SynDiesel® & SynJet™

- Western Offshore
  - 20° API, <300 cSt, PUB
- Western Refining
  - 20° API, <300 cSt, PUB
- USA Western Refining
  - 20° API, <300 cSt, PUB

- 20° API, <300 cSt, PUB
- 20° API, <300 cSt, PUB
- 20° API, <300 cSt, PUB

Alberta
CDN/USA Border

USA
Eastern Refining
Conclusions

• **Full Bitumen Upgraders:**
  – Not economically feasible in Alberta for near future

• **Partially Upgraded Bitumen (PUB) Advantages:**
  – Pipelineable without diluent - No Diluent recycle required
  – PUB is significantly higher in distillate content and lower in sulfur, heavy metals, TAN and CCR compared to regular DilBit.
  – Exhibits high carbon retention - reduction of CO2 emissions
  – Increase in product volume yield (up to 30%)
  – Partial or Targeted Upgrading can meet specific refinery feedstocks
  – No waste products of pet coke, asphaltenes and HFO
  – Partial Upgraders can be built as multiple satellite facilities (as low as 10,000 bpd) or as centralized plants (>50,000 bpd)
Thank you
Bitumen Partial & Targeted Upgrading: The Next Step

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