Feasibility of Partial Upgrading of Athabasca Bitumen

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STUDY OBJECTIVES
Study Objectives

• Develop Relatively Simple, Technically Proven “Field” Technology to Partially Upgrade Athabasca Bitumen
  • Produces a Stable, Saleable SCO and a Heavy Hydrocarbon Reject Stream
  • Processing Steps Employed Based on Consultants Expertise of Existing Upgrading Processes
Study Objectives (Cont’d)

• Evaluate Economic Feasibility of Process for Both In-Situ (SAGD) and Mining Projects
  • Develop Material and Energy Balances, Investment and Operating Costs
  • Integration of Process with SAGD or Mining
  • Estimate Profitability and Determine Sensitivity to Light-Heavy Price Margin and Oil and Natural Gas Prices
    • Revenues Compared to DilBit Production
• Develop Process Configuration for Minimizing Carbon Emissions (CO₂ Capture) and Estimate Profitability
PARTIAL UPGRADING
What is Partial Upgrading?

- **Objective:** Produce Transportable SCO from Heavy Oil Feedstocks
- **SCO will Resemble 20°API Heavy Crude**
- **Typically Implemented in the Field, Near Resource Location**
- **Characterized by:**
  - Relatively Low Investment
  - Simple Processing Configuration
  - Produces Heavy Unconverted ByProduct
- **Issues Concerning SCO Value and Stability**
Partial Upgrading Process

- Utilizes Proven Processing Steps
- Minimal R&D Required to Validate and Confirm Yields and Costs
- Requires Relatively Small Quantity of Hydrogen
- Completely Eliminates the Need for Diluent
- Results in a 78 V% Yield of Stable SCO
- Bottoms Reject Product can be Utilized for Energy Production
STUDY BASIS AND CASES INVESTIGATED
Important Parameters and Assumptions - Technical

- *SAGD Steam to Oil Ratio of 2.5*
- **Bitumen Production Rate**
  - SAGD: 50,000 BPSD
  - Mining: 150,000 BPSD
- **Natural Gas Liquid Used as Diluent for Base DilBit Case**
  - Blending Ratio of ~40 Bbl Diluent/Bbl of Bitumen
- **Partial Upgrading plus Bottom Reject Processing Facility Includes all Offsites and Utilities**
Important Parameters and Assumptions - Economic

- **Western Canadian Location**
- **2010 US $ Basis**
- **Base Light Oil (WTI) Price of $80/Bbl**
- **Natural Gas Price = 50% of WTI Price (Energy Basis) = $6.67/MM Btu**
- **94% On-Stream Time**
- **20 Year Project Life**
- **Investments Include Offsites, Owners’ Costs and Contingency**
- **Power Cost of $50/MW-Hr**
- **“Tax” of $30/MT of CO₂ to Evaluate CO₂ Capture Cases**
DilBit and SCO Values

• **Diluent Price is a Premium over the Light Oil Price**
  • Premium is a Function of Light-Heavy Oil Margin
  • Premium is Typically 5 – 20%

• **DilBit and SCO Values are Estimated from Valuation Model**
  • Estimated Value is a Function of Oil Inspections Including Gravity, Sulfur and Residue Content
  • Model Results are Calibrated with Average Historical Data on a Known Crude or Blend (e.g. CLB or LLB)
  • Historical Average for DilBit is a 25-30% Differential

• **Alternate Case with Small Light-Heavy Oil Margin also Evaluated**
  • DilBit Set at 90% of Light Oil Price
  • SCO Price Estimated at 90 - 100% of Light Oil Price
  • Representative of Situation in 2009/2010 Timeframe
SAGD Study Cases Evaluated

• **Base Case**
  - DilBit Production
  - Natural Gas Utilized to Produce Required SAGD Steam
  - Natural Gas Liquids Used as Diluent

• **Case 1 – FBC for SAGD Steam Production**
  - Partial Upgrading / SCO Production
  - Diluent Returned to Field
  - Reject Product Sent to Fluidized-Bed Combustor to Produce Steam Required for SAGD
    - *Possible Extra HP Steam Used to Produce Power*
  - SMR Used to Produce Hydrogen for Partial Upgrading
Case 2 – Gasification for SAGD Steam and H₂ Production

- Partial Upgrading / SCO Production
- Diluent Returned to Field
- Reject Product Sent to Oxygen Fed Gasifier
- Gasifier Syngas is Split
  - Majority is Combusted to Produce Steam for SAGD
  - Smaller Quantity Used to Produce Hydrogen for Partial Upgrading

Case 3 – Gasification (IGCC) for H₂ and Power Production

- Partial Upgrading / SCO Production
- Diluent Returned to Field
- Reject Product Sent to Oxygen Fed Gasifier to:
  - Produce Steam for Process (not for SAGD)
  - Produce Hydrogen for Partial Upgrading
  - Produce Significant Power via IGCC
Mining Study Cases Evaluated

• **Base Case**
  - DilBit Production
  - Natural Gas Liquids Used as Diluent

• **Case 4 - Gasification (IGCC) for Hydrogen and Power Production**
  - Similar to Case 3 but at Larger Scale
  - Partial Upgrading / SCO Production
  - Diluent Returned to Field
  - Reject Product Sent to Gasifier to:
    • Produce Steam for Process
    • Produce Hydrogen for Partial Upgrading
    • Power via IGCC
CO₂ Capture Alternate Cases

- **For Each Case (1 through 4) also Examined Alternate Design where CO₂ is Captured and Compressed**
  
  - **Case 1**
    - OxyCombustion in FBC
    - CO₂ Capture in SMR
  
  - **Case 2**
    - CO₂ Capture in Gasification Plant
    - Hydrogen Rich (~90%) Stream (from Upstream of PSA) Combusted to Produce SAGD Steam
  
  - **Cases 3 and 4**
    - CO₂ Capture in Gasification Plant
    - Hydrogen Rich Stream (Upstream of PSA) Sent to Gas Turbine in IGCC to Produce Power
STUDY RESULTS
Study Results

- **SCO Yield and Quality**
  - Yield of 78 V% on Bitumen Feed
  - API Gravity and Viscosity Similar to DilBit
  - Lower Residue, Metals, CCR, Sulfur and Asphaltenes
  - Stable (Low Asphaltene Content)

- **Effect of CO₂ Capture (with $30/MT Tax) also Shown in Each Figure**

- **Project Investment (See Figure)**
  - Includes Partial Upgrading and Reject Stream Processing Facilities
  - Lowest Investment for FBC (Case 1), Highest Investment for IGCC (Case 3)
• **Net Revenues (over DilBit Production) and Project Pre-Tax IRR Shown in Figures**

  • Net Revenue is **Incremental Revenue** to Heavy Oil Producer if Partial Upgrading with Reject Processing is Utilized Instead of DilBit Production

  • Net Revenues are:

    - *Partial Upgrading Revenues (SCO Sales)*
      - *Partial Upgrading Operating Costs*
      - *DilBit Gross Revenues (DilBit Sales)*
      + *DilBit Diluent Cost*
      + *DilBit Natural Gas Cost (if SAGD Steam Produced via Reject Processing)*
## Bitumen, DilBit and SCO Inspections

<table>
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<th>Inspection</th>
<th>Bitumen</th>
<th>DilBit</th>
<th>Study SCO</th>
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<tbody>
<tr>
<td>Gravity, °API</td>
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<td>Viscosity@4°C, cSt</td>
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<td>&lt;350</td>
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<td>Sulfur, W%</td>
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<tr>
<td>Vacuum Residue, V%</td>
<td>56</td>
<td>43</td>
<td>42</td>
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<tr>
<td>CCR, W%</td>
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<td>12</td>
<td>5</td>
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<tr>
<td>Nickel + Vanadium, Wppm</td>
<td>300</td>
<td>80</td>
<td>50</td>
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<tr>
<td>Asphaltenes, W%</td>
<td>11</td>
<td>8</td>
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Estimated Investment

Investment, $MM

No CO2 Capture
CO2 Capture

SAGD
Mining

Case 1
Case 2
Case 3
Case 4
Annual Net Revenues Over Base Case

No CO2 Capture
CO2 Capture

SAGD
Mining

Case 1
Case 2
Case 3
Case 4

Annual Net Revenues over Base Case, $MM
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Project Pre-Tax IRR

Case 1 Case 2 Case 3 Case 4

No CO2 Capture CO2 Capture

Mining SAGD
Project Pre-Tax IRR Including Consequence of Tax w/o Capture

<table>
<thead>
<tr>
<th>Case</th>
<th>No CO2 Capture</th>
<th>No CO2 Tax</th>
<th>No CO2 Capture with CO2 Tax</th>
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<td>SAGD</td>
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</tbody>
</table>

0% 2% 4% 6% 8% 10% 12% 14% 16% 18% 20%

Case 1  Case 2  Case 3  Case 4
SENSITIVITY STUDIES
Parameters Investigated

- **IRR vs. WTI Price**
  - Also Affects Natural Gas Price since Study Gas Price is Set as a Percentage of WTI

- **IRR vs. Assumed Natural Gas Price as a Percentage of WTI Price (Energy Basis)**
  - Values of 30, 50 and 75% Investigated

- **Net Annual Revenues at Small Light to Heavy Oil Price Differential**
  - Heavy Oil (LLB Type) at 90% of Light Oil Price
    - Nearly All Cases have Negative Net Revenue when Compared to Base DilBit Case
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IRR as a Function of Oil Price

CO₂ Capture (Tax) Cases

Pre-Tax IRR, %

WTI Price, $/Bbl

Case 1
Case 2
Case 3
Case 4
Case 1 (No CO$_2$ Capture) IRR as a Function of Oil & Gas Prices

![Graph showing IRR as a function of WTI price with different gas price scenarios: Nat Gas = 30% WTI Price, Nat Gas = 50% WTI Price, Nat Gas = 75% WTI Price.](image)
STUDY FINDINGS & ADDITIONAL DETAILS
Important Findings

SAGD Project

• **Partial Upgrading can be Profitable (IRR > 10%) with WTI at $80/Bbl, Natural Gas at 50% of WTI Price and Light-Heavy Margin at Historical Averages**
  
  • Either FBC or Gasification of HC Reject Stream
  • Integrated with Upstream SAGD to Produce Required Steam

• **Power Production (IGCC) from HC Reject Stream Indicates Lowest IRR**
  
  • Not Economical Feasible at SAGD Scale (50,000 BPSD)
Important Findings
SAGD Project (Cont’d)

• **Higher Oil Prices Result in Higher Project Revenues Relative to DilBit Production**
  - IRR Nearly Doubles at $120/Bbl WTI Price

• **In a Carbon Tax Environment**
  - Without Carbon Capture (Pay Tax): FBC of HC Reject Stream is Favored over Gasification
  - With Carbon Capture: Gasification of HC Reject Stream is Favored over Oxygen fed FBC

• **With a Small Light-to-Heavy Oil Margin, DilBit Production is Favored**
Important Findings

Mining Project

- **SCO Production and Significant Power Production from Partial Upgrading Reject Stream (via IGCC) has Approximate 10% Return**
  - Not Significantly Affected by Natural Gas Price
- **Similar Profitability for Carbon Capture/Tax Situation with Approximately 5% Incremental Investment**
- **With a Small Light-to-Heavy Oil Margin (i.e. 10%)**
  - Large Revenue Loss When Compared to DilBit Production
For Additional Information

- **Detailed Study Report can be Purchased from Colyar Consultants**

- **Study can be Customized for:**
  - Specific Crude and Feedrate
  - Alternate Bottoms Reject Use
  - Upstream Requirements
  - Economic Parameters