In-situ Extra Heavy Oil Production - benchmarking of CO₂ capture solutions

Karina Hofstad, Knut Ingvar Åsen, Kjersti Wilhelmsen, Erik Mikkelsen

2nd Oxyfuel Combustion Conference

Yeppoon Australia, 12th - 16th September 2011
Contents

• Statoil’s Extra Heavy Oil Activity (EHO) in Canada
• Extra Heavy Oil Value Chain
• CO2 Capture Options for a Steam Assisted Gravity Drainage (SAGD) Facility
• Study Basis
• Comparison of CO2 capture technologies
  – Energy consumption, emissions and avoided CO₂
  – Capex/Opex/CO₂ Avoided Cost
• Conclusion
Statoil’s Extra Heavy Oil Activity in Canada

- Established in Calgary, 2007
- 1,100 km² of oil sands leases
- Estimated 2.2 bn bbl recoverable reserves
  - Kai Kosh Deshe Project (KKD) (~>200 kb/d)
  - Acquisition of a 40% interest by PTTEP (Nov 2010)
  - Statoil retains operatorship
Statoil Leismer and KKD Project

- First phase (18.8 kb/d) of Kai Kosh Deshe (KKD) Project
- Successful commissioning and start-up of Leismer Demonstration Project
  - First steam Sept 3, 2010
  - First SAGD Oil January 2011

- KKD Project
  - ~>200 kb/d
  - Regulatory Approval (Jan 2011)
    - 40,000 b/d Leismer
    - 40,000 b/d Corner
**EHO SAGD Production**

- The most common method for in-situ Extra Heavy Oil (EHO) production is Steam Assisted Gravity Drainage (SAGD).
- Injection of steam into the reservoir to reduce the viscosity of the bitumen.

- Steam is produced by Once Through Steam Generators (OTSGs).
- SAGD may require a Steam to Oil Ratio (SOR) of 2.5-3.0.
- **With natural gas as the main fuel the CO2 emission per produced barrel of heavy oil is very high (60–80 kg/bbl).**
EHO Value Chain

- **Diluent Purchases** (Syncrude or condensate)
- **Bit Blend Purchases**

**SAGD Facilities**
- Natural Gas
- Power
- Water
- Steam

**Pipelines & Terminals**
- Diluent
- Bit Blend

**Upgrader**
- Light Ends
- Diluent
- SCO
- Byproducts
  - Coke
  - Sulphur
- Water
- Utilities
  - Natural Gas
  - Power

**Synbit or Dilbit Sales**
SAGD EHO Production Facility
Reference Case - no CO2 capture
Study basis

- **Bitumen Production Capacity**
  - 60 000 bbl/d

- **Steam Production from 9 OTSG’s**
  - ~30 000 ton/d saturated steam at 90 bar
  - Steam quality from OTSG 75% steam (25% condensate)
  - Emitting 1.6 mill ton CO2/y

- **Dry NG from grid (>91% CH4) (additional produced gas from EHO wells)**

- **Electricity is imported from grid**

- **Cooling: air cooling and glycol/water mixture**

- **CO2 product specification**
  - CO2 >99 vol%
  - H2O <50 ppm
  - 220 Bar

- **Statoil in house modelling and economic tools for dimensioning and costing**
CO₂ Capture options

- Post-combustion (MEA)
- Pre-combustion (H₂ production)
- Oxy-combustion
Energy Consumption

<table>
<thead>
<tr>
<th>Energy Consumption</th>
<th>Ref. Case no capture</th>
<th>Post-combustion</th>
<th>Oxy-combustion</th>
<th>Pre-combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NG + produced gas) consumption (MJ/bbl)</td>
<td>1313</td>
<td>1650</td>
<td>1282</td>
<td>2045</td>
</tr>
<tr>
<td>Electric power import (kWh/bbl)</td>
<td>20</td>
<td>36</td>
<td>58</td>
<td>32</td>
</tr>
<tr>
<td>Total energy input (MJ/bbl)</td>
<td>1458</td>
<td>1910</td>
<td>1700</td>
<td>2276</td>
</tr>
<tr>
<td>Additional energy consumption (%)</td>
<td>31</td>
<td>17</td>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

50% efficiency assumed for power production

- Oxy-combustion CO₂ capture has the lowest additional energy consumption
Emissions and CO$_2$ avoided

- Superior HSE performance (in principle a «closed» system offering almost full CO$_2$ capture)
- Less complex
Relative CAPEX

<table>
<thead>
<tr>
<th>CAPEX</th>
<th>Post-combustion</th>
<th>Oxy-combustion</th>
<th>Pre-combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 capture section</td>
<td>1.0</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>General utilities</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Air cooling section</td>
<td>1.0</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td>SUM CAPEX</td>
<td>1.0</td>
<td>0.9</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- Pre-combustion CAPEX is 50% higher than post- and oxy-combustion
- Post-combustion and oxy-combustion capture is in the current estimate quite similar
Relative CO2 avoided cost

- CO2 avoided cost (Capex and Opex)

<table>
<thead>
<tr>
<th>Process</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-combustion</td>
<td>1.0</td>
</tr>
<tr>
<td>Oxy-combustion</td>
<td>0.9</td>
</tr>
<tr>
<td>Pre-combustion</td>
<td>1.6</td>
</tr>
</tbody>
</table>

- Opex cost
  - Pre-combustion has very high operational costs
  - Oxy-combustion is less sensitive to escalating energy cost
    - natural gas vs. electricity price spread is important
Conclusion

• Pre-combustion capture is not favourable regarding neither total energy demand, avoided rate nor CO$_2$ avoided cost

• Oxy-combustion has the lowest total energy demand per bbl of EHO produced

• Post-combustion and oxy-combustion show very similar CO$_2$ avoided when electricity import is based on natural gas

• For SAGD, oxy-combustion capture is a promising option regarding energy consumption and CO$_2$ avoided cost
Thank you

In-situ Heavy Oil Production - benchmarking of CO2 capture solutions

Karina Hofstad
Principal Researcher Process Downstream
khho@statoil.com, tel: +47 48 02 78 53
www.statoil.com