Design Characteristics of an Oxy Combustion Steam Plant for Canadian Oil Sands with a Focus on Sustainability

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Agenda

- **Context – Oil Sands & Steam Assisted Gravity Drainage**
  - Base case description
    - Air boilers
    - Steam production
  - Oxy case description
    - Details on oxy burners
    - Details on oxy boilers
    - Details on ASU
    - Details on CPU
- **Results & path forward**
Context – Athabasca Oil Sands
Steam Assisted Gravity Drainage
Athabasca Oil Sands & SAGD

- Athabasca Oil Sands = Northern Alberta Bitumen reserve

- Represents more than 70% of world’s bitumen reserve

- Energy intensive / carbon intensive extraction process: SAGD (Steam Assisted Gravity Drainage)
  - In addition to energy efficiency improvements, CCS a potential solution to reduce environmental impact

- Joint effort to develop a Sustainable way to use the SAGD process between Statoil RDI, Babcock & Wilcox and Air Liquide
  - Oxy-combustion boilers with CCS to produce carbon-free steam
  - Case study:
    - Generic 40,000 bbl/day SAGD facility
    - 875 tonnes/day steam consumption
Base case description
Reference case

- Reference scheme - air case

Air

N\textsubscript{2}

O\textsubscript{2}

Natural Gas

Flue Gas

\textbf{CO}_\textsubscript{2} \rightarrow \textit{emissions}

X 3

Steam for SAGD

875 Tonnes/day

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Initial boiler design – 100% air combustion

- 3 identical TSSG® boilers - 875t/hr saturated steam at 91 bar & 304°C

- Specifically designed for oil sands
  - Transport constraints
  - Robust design can accept « Sub-ASME » water quality from water treatment evaporator including multi-circ concept

- High efficiency
  - Low boiler blowdown (2.5 to 5% of steam flow) to conserve water
  - Incorporating glycol gas/air heater to boost boiler efficiency

- Ultra low NOx combustion burners with FGR to meet Alberta’s stringent NOx emissions requirement (15.8 g/GJ)

- Incorporating features ready for future conversion to oxy combustion with minimum modifications to the boiler to accommodate oxy burners
Oxy-combustion solution description
**Oxy-combustion case – general scheme**

- **Flue Gas Recycle**
  - Install TSO dampers

- **CO₂ rich Flue Gas**
  - Install oxy train control skids
  - Replace air burners with Air Liquide’s flexible oxy/air burners
    - Modify windbox and burner opening
    - Add FGR feeders to each burner

- **Cryocap™ Oxy**
  - CO₂ for transport & storage
    - High purity (>99%)
    - Supercritical conditions

- **Natural Gas**
- **ASU**
- **N₂**
- **O₂**
- **TSSG® Boiler X 3**
- **Steam for SAGD**

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Flexible air / oxy burners

- Efficient design
  - Low CO production
  - Low NOx (O2 / air staging, FGR use)

- Compact design
  - Compliant with pressure drop specs
  - Optimized burner-burner spacing
  - Controlled flame shape and interaction

- Flexible design
  - No mixing of FGR with oxygen
  - Wide range of FGR rate acceptable
  - Oxy / air flexibility

High flexibility of operation with excellent performance

Interesting alternative for capture ready projects

Fuel

Oxygen

FGR/Air

Air Liquide, world leader in gases for industry, health and the environment
Oxy/Air combustion boilers

- Switching between air and oxy combustion modes and vice versa possible while the boiler is online

- Boiler is operated in positive pressure to eliminate air infiltration to boiler

- 2% higher boiler efficiency in oxy combustion as compared to air combustion
Technology qualification

- **B&W TSSG® boilers**
  - 1100 T/h total capacity in operation in Alberta Oil Sands (add 1100 T/h coming on-line 2014-15)
  - AL flexible Oxy/air burners for similar application demonstrated at Lacq

- **ASU technology**
  - Fully qualified improvements to commercial technology
  - Air Liquide referenced for large scale ASU in Alberta

- **Cryocap™ Oxy technology**
  - All technology bricks demonstrated in representative or more stringent conditions through various demo plants

**Total Lacq**

**Callide**

**Ciuden**
High efficiency ASU for oxy-combustion

- Oxy combustion
  - ASU design = air distillation at lowest possible pressure (< 4bar)

**Separation Energy* in kWh / t O₂**

*Compression energy not included, calculated at 15 °C, 1 atm, 60% humidity*
ASU: High energy efficiency solution for SAGD

- ASU efficiency chosen: XLE solution
  - Very efficiency ASU: Specific energy < 170 kWh/tonne (w/o heat integration)

- Cold atmospheric conditions (Alberta)
  - reduced energy consumption

- Compressor technology
  - Axial machine → high efficiency
Cryocap™ Oxy scheme

- Natural gas flue gas = Clean flue gas (ex: no SOx treatment needed)
- **Near Zero Emissions** of CO₂, CO, NOₓ
- High energy efficiency
  - Separation + compression energy < 125 kWh/tonne

* See dedicated AL presentation
Results & Path forward

Viability of oxy-combustion for SAGD
Capture rate

- From direct emissions: ability to capture **98% of the CO₂**

- CO₂ intensity of electricity is critical in the overall carbon footprint
  - Today’s CO₂ intensity in Alberta > 1 tonne of CO₂ / MWh
  - Alberta objectives of CO₂ intensity reduction will reduce carbon footprint greatly
Efficiency comparison between post and oxy

- Comparison with a post-combustion case (amines)
  - Extra boiler for production of regeneration steam
  - Capture from all boilers
- Conversion of all consumers into heat input
- CO₂ avoided Specific Energy Consumption

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<thead>
<tr>
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<th>Amines case</th>
<th>Oxy case</th>
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<tbody>
<tr>
<td>CO₂ capture SEC</td>
<td>4,8</td>
<td>2,0</td>
</tr>
<tr>
<td>CO₂ avoided SEC</td>
<td>6,5</td>
<td>2,2</td>
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Conclusions

- Fully integrated oxy-combustion SAGD plant with CO₂ capture is feasible
- All components in an oxy SAGD is ready for demonstration in full scale
- Efficiency of oxy-combustion solution is significantly better than efficiency of post-combustion solution for a SAGD facility where surplus LP steam is not available
- Solution is ready for broad adoption upon sufficient CO₂ tax / legislation deployment
End of presentation
Thank you for your attention

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