CO₂ Capture Project (CCP) – Phase 3 Results and Phase 4 Program Development

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CO₂ Capture Project (CCP) - Background

Over 15 years of support for CCS technology development

A collaboration among major oil & gas companies that covers capture, storage, economics and policy aspects of CCS.

CCP4: “Advancing CCS technology deployment and knowledge for the oil and gas industry”
Characteristics of CO₂ Emissions in the Oil & Gas Sector

Diverse Operations
• Refinery: FCC, heaters and boilers (H&Bs), cogens, SMR
• Heavy oil production: Once-through steam generators (OTSGs), cogens
• NGCC power generation
• LNG production: Gas turbine drivers
• Natural gas production

Dispersed CO₂ Sources
• Operations are scattered over a large area (e.g., heaters and boilers); flue gas cannot be combined
• Cannot take advantage of “economy of scale” due to relatively small CO₂ volumes in some streams
• Restrictions on the available plot space in congested refineries

Diverse CO₂ Gas Stream Characteristics
• CO₂ concentration in flue gas varies from 4–20 mol%. CO₂ in SMR H₂ plants available at high pressure (~20 bar)
• CO₂ emissions from a single source can vary from <100 tpd to >3,000 tpd
• Flue gas stream mostly clean with no particulates and SOx components

However, the fundamentals of CO₂ capture remain the same and knowledge gained in the power industry can still be applied
CCP3 Program Objective: Move CCS towards commercial deployment by

- Increasing technical and cost knowledge
- Supporting the development of technologies to reduce CO₂ capture costs by 20-30%

Scenarios
- Refinery: FCC, heaters and boilers (H&Bs), SMR
- Heavy Oil: Once-through steam generators (OTSGs)
- NGCC

Approach
- Perform independent assessment of novel capture technologies
- Support lab, bench and pilot scale studies
- Carry out detailed economic assessment of select technologies

CCP3 Program – At a Glance
- 21 Technical Studies by Foster Wheeler
- 2 Demonstrations (oxy-fired FCC, oxy-fired OTSG)
- 4 bench/pilot projects (oxy-burner testing, Pd membrane, CLC, enzyme post-C)
- 1 pilot test post-C solvent screening program (EERC)
- 5 preliminary evaluations of novel technologies
- 24 in-house economic evaluations
Oxy-FCC demonstration project
- 33 bpd hydrocarbon feed unit (~1 tpd CO₂ emission)
- Host: Petrobras, Brazil
- The field demonstration run confirmed the technical viability of the process.
- FCC in oxy-firing mode can enable a higher throughput (up to 3%) or allow a switch to processing heavier oil feeds while keeping the same product yield.
- Corrosion in the recycle compressor needs to be addressed.

Economic assessment studies
- Refinery FCC: Post-C has cost advantage over oxy-C; however, the possibility of additional feed throughput may make oxy-C favored over post-C.
Oxy-OTSG demonstration project

- 50 MMBtu/h fuel input (~75 tpd CO₂ emission)
- Host: Cenovus Energy, Canada
- The field demonstration run confirmed the technical viability of the process.
- Similar temperature and flux profiles in air and oxy-firing

Air-firing  Oxy-firing

- Suncor – Project Administrator, Project Manager
- Cenovus Energy – Site Participant, Project Leader
- Praxair, Inc. – Site Participant, Project Leader
- Other project partners and co-funders: CCEMC, CCP3, MEG Energy, Devon and Statoil

Image courtesy of Cenovus Energy Inc.
CCP3 Economic Results

- Basis: 1Q 2014 costs
- Post-combustion solvent-based technology is still the most economic (or close second).
- The economic assumptions, such as, fuel cost, location factor, imported power cost/CO₂ footprint, process scale/configuration all have an impact on the cost numbers.

<table>
<thead>
<tr>
<th></th>
<th>CO₂ captured</th>
<th>CO₂ captured</th>
<th>CO₂ avoided</th>
<th>CO₂ capture cost</th>
<th>CO₂ avoided cost</th>
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<table>
<thead>
<tr>
<th>Refinery – USGC</th>
<th>Fuel</th>
<th>CO₂ captured</th>
<th>CO₂ captured</th>
<th>CO₂ avoided</th>
<th>CO₂ capture cost</th>
<th>CO₂ avoided cost</th>
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<tbody>
<tr>
<td>FCC</td>
<td>Post-C</td>
<td>Carbon</td>
<td>55.5</td>
<td>85.5</td>
<td>65.5</td>
<td>85</td>
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<tr>
<td>FCC</td>
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<td>Fuel gas</td>
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<td>58.4</td>
<td>85.5</td>
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<tr>
<th>Oil Sands Steam Generation – Fort McMurray, Canada</th>
<th>Fuel</th>
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<th>CO₂ captured</th>
<th>CO₂ avoided</th>
<th>CO₂ capture cost</th>
<th>CO₂ avoided cost</th>
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<tbody>
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<td>Post-C</td>
<td>Nat gas</td>
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<td>90.0</td>
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<tr>
<td>OTSGs</td>
<td>CLC</td>
<td>Nat gas</td>
<td>63.3</td>
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<th>CO₂ capture cost</th>
<th>CO₂ avoided cost</th>
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### CCP4 Focus

- **Tactical Demonstration (near-mid term)** -> Incremental improvement technologies (e.g., SMR pre-combustion capture)

- **Strategic Deployment (mid-long term)** -> Breakthrough technologies (e.g., post-combustion capture)

### CCP4 Projects Under Consideration (partial list)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Project/Study</th>
<th>Activities</th>
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<tbody>
<tr>
<td>Refinery</td>
<td>SMR pre-C capture technology development (mid-to-high TRL)</td>
<td>Perform economic assessment of a novel capture technology and support development</td>
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<tr>
<td>Various</td>
<td>Identify breakthrough technologies for post-C capture</td>
<td>Carry out techno-economic evaluations and support development</td>
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<tr>
<td>NG Treating</td>
<td>Understand/identify technologies for offshore CO₂ removal</td>
<td>Perform technology landscape study followed by a technology development</td>
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Summary and Conclusions

• Post-, pre- and oxy-combustion technologies were investigated at lab, bench, pilot and demo scale

• Post-combustion solvent-based technology is still the most economic (or close second)
  • Oxy-combustion not feasible or economically attractive (except for FCC)

• CO₂ avoidance costs are very high, especially for the Heavy Oil scenario due to the Alberta location

• Results from CCP3 are being used to develop the CCP4 program
  • Near to mid term – focus on incremental improvement (e.g., SMR pre-C capture)
  • Mid to long term – focus on breakthrough technologies (e.g., post-C capture)
Acknowledgment

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Capture Team Members
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Questions/Discussion?