QUEST CCS PROJECT

PCCC2 CONFERENCE
BERGEN, NORWAY
SEPT 19, 2013

STEVE PEPLINSKI – QUEST ENGINEERING MANAGER
Introduction - The Athabasca Oil Sands Project

Muskeg River Mine

Corridor Pipeline

Scotford Upgrader

Scotford Refinery (Shell only)

Bitumen to Synthetic Crude (255,000 BPD)
**GENERAL FEATURES**

- **QUEST CCS PROJECT - FULLY INTEGRATED CCS (CAPTURE, TRANSPORT & STORAGE)**
- **JV AMONG SHELL (60%); CHEVRON (20%); AND MARATHON (20%) - PART OF AOSP**
- **LOCATED AT SCOTFORD UPGRADER COMPLEX**
- **ONE MILLION TONNES CO₂ PER YEAR CAPACITY FOR 25 YEARS**
- **35% REDUCTION OF UPGRADER CO₂ EMISSIONS**
- **PROJECT APPROVAL - SEPT 2012**
**HARDWARE**

- **Capture at the Scotford Upgrader from 3 Hydrogen Manufacturing Units**

- **CO₂ transported by 12 inch pipeline to storage, with 6 inch laterals**

- **Pipeline to 65 km north of the Upgrader**

- **Route selected to meet stakeholder requirements:**
  - 28 km follows existing ROW
  - Drilled under North Saskatchewan River
  - 30+ re-routes to accommodate landowner wishes

- **Base plan: 3 injection wells and associated monitoring**
Saline Aquifer Storage

Injection Formation - Basal Cambrian Sands (BCS)

- 2,300 m depth, Prairies deepest sandstone
- Multiple caprock and salt seal layers in the storage complex
- No significant faulting visible from wells or seismic
- The BCS is well below hydrocarbon bearing formations and potable water zones in the region
- Relatively few wells drilled into the BCS, none within 10 km of the proposed storage site

Wells and Drilling

Conventional Drilling Methods
**TIMELINE AND UPCOMING ACTIVITIES**

- **WELL PROGRAM**
  - Drilling finished, completions ongoing

- **CAPTURE & PIPELINE**
  - Engineering finalized
  - Site underground construction complete
  - First module delivery Q4 2013
  - Major equipment deliveries complete
  - Pipeline construction begins Q3 2013

- **COMMUNITY ADVISORY PANEL**
  - Initial kickoff in January, with regular updates

- **FINAL REGULATORY APPROVALS**
  - Pipeline laterals expected end 2013
1. WHY ACTIVATED AMINE (ADIP-X)?

2. HMU INTEGRATION ISSUES

3. CO2 COMPRESSION, INTEGRATION WITH PIPELINE AND WELLS
**WHY ACTIVATED AMINE (ADIP-X)?**

**PROCESS SELECTION COMPLETED IN Q1 2010 WITH THE FOLLOWING CONSTRAINTS:**

- **DESIGN BASIS CAPACITY OF 1.2 MILLION TONNES PER YEAR, ON-STREAM FACTOR OF 90% = 1.08 MILLION TONNES PER YEAR CALENDAR DAY CAPACITY**

- **MAXIMUM PRESSURE DROP THROUGH THE CO₂ FACILITY LESS THAN 70 KPA**

- **TEMPERATURE OF THE PSA INLET GAS AFTER CO₂ CAPTURE SHALL NOT EXCEED 35°C IN ORDER TO MAINTAIN THE H₂ ABSORPTION CAPACITY**

- **CHEMICAL SOLVENT CARRYOVER TO THE PSA SHOULD BE LESS THAN 1 PPMW. CHEMICAL SOLVENTS CAN CONTAMINATE THE PSA’S ADSORBENTS.**

- **ONSITE ELECTRICAL POWER AVAILABILITY LIMITED DUE TO HV SUBSTATION CONSTRAINTS**
### WHY ACTIVATED AMINE (ADIP-X)? - CO₂ SOURCE SELECTION

**Scotford Upgrader**

#### Pre-combustion

- **Steam Methane Reformers**
  - **Parameter**
    - **System Pressure**
    - **CO₂ Concentration**
    - **CO₂ Partial Pressure**
    - **Other Impurities**
    - **Plot Space**

#### Post-combustion

- **Fired Heaters**
  - **Boilers**
  - **Gas Turbines**

**Plot Space**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Post-comb</th>
<th>D/S of PSA</th>
<th>U/S of PSA</th>
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<td>System Pressure</td>
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<td>CO₂ Concentration</td>
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## Why Activated Amine (ADIP-X)?

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>ADIP-X</th>
<th>MDEA</th>
<th>SELEXOL</th>
<th>MEMBRANE</th>
<th>PSA</th>
<th>METHANOL ABSORPTION</th>
<th>AMMONIA ABSORPTION</th>
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<tr>
<td>HSE RISKS</td>
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<td>HMU RELIABILITY EFFECTS</td>
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### Influencing Factors

- **Construction in brownfield location influenced 75% of options**
- **Commercial scalability unproven for 5 of 8 options**
- **Local OPEX factors - steam versus electricity costs**
**QUEST - CAPTURE FACILITIES**

**SCOTFORD UPGRADER**

![Diagram of Scotford Upgrader](image)

- **CO₂**
- **CO₂ TO ATMOSPHERE**
- **STEAM**
- **HC GAS**
- **REFORMER**
- **HP STEAM**
- **UTILITIES**
- **PSA**
- **H₂**
- **HYDROCRAC KERS (UPGRADER & REFINERY)**

1. **Hydrogen Unit**

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1. **Hydrogen Unit**
Heavy Oil
Shell Canada
Capture 3D Model – Amine Stripper & CO2 Compression

Amine Stripper
Compression Building
TEG Dehydration
Compressor
Intercooling

PCCC2 Conference
SEPTEMBER 19, 2013
INTEGRATION WITH EXISTING HMUS

- **HMU operation**
- **Steam**
- **Steam + NG**
- **Makeup fuel**

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**Product H2**

- **PSA Adsorbent Fill**
- **Control System**

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**Loss of CO2**

- **CH4 + Slip H2 & CO2**
- **Off gas fuel**

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**H2 Manufacturing Unit**

- **Amine Unit**
- **Compressor**
- **Pressure Swing Adsorption (PSA)**
- **H2 Separation**

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**Storage Complex**

- **Storage Site**
- **CO2 Pipeline**
- **Dense Phase Transport**
- **Capacity**
- **Let Down at Choke Valve**
- **CO2**

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HEAVY OIL SHELL CANADA

PCCC2 CONFERENCE

RESTRICTED SEPTEMBER 19, 2013 15
INTEGRATION WITH EXISTING HMUS

- WHAT DOES HMU DO WHEN QUEST IS ONLINE/OFFLINE?
  - VERIFY REFORMER BOX TRIP OCCURRENCES VIA DYNAMIC ANALYSIS
  - CONFIRM STEAM BALANCE WITHIN HMUS FOR FGR ON/OFF

- LOSS IN H2 PRODUCTION DUE TO QUEST?
  - PSA REVISED ADSORBENT FILL TO POST QUEST OPTIMIZED LOADING

- 70 KPA PRESSURE DROP FORCED PIPING UPSIZING

- ISSUES – REMOVING CO2 IMPACTS HMU NOX PRODUCTION
  - LOW NOX BURNERS C/W TESTING (BURNER MANAGEMENT SYSTEM RELOOK)
<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Air Contaminant/Parameter</th>
<th>Current Limit</th>
<th>Requested Limit</th>
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</thead>
<tbody>
<tr>
<td>Expansion HMU flue stack (S-44103)</td>
<td>Nitrogen oxides</td>
<td>62.7 kg/h</td>
<td>130.0 kg/h</td>
</tr>
<tr>
<td>Base plant Train 1 hydrogen manufacturing unit flue stack (S-24103)</td>
<td>Nitrogen oxides</td>
<td>47.5 kg/h</td>
<td>76.5 kg/h</td>
</tr>
<tr>
<td>Base plant Train 2 hydrogen manufacturing unit flue stack (S-24203)</td>
<td>Nitrogen oxides</td>
<td>47.5 kg/h</td>
<td>76.5 kg/h</td>
</tr>
</tbody>
</table>

Scotford HMU NOx Reduction (Total)
HMU 1 & 2 SCOPE

Amine Absorbers
Flue Gas Recirculation
COMPRRESSOR OPERATING ENVELOPE
INTEGRALLY GEARED, 8 STAGES WITH INLET
GUIDE VANES

Pressure, Mpa

0.8  0.9  1.0  1.1  1.2  1.3  1.4  1.5

Flow rate, Million tpa

0.8  0.9  1.0  1.1  1.2  1.3  1.4  1.5

PSV Set Pressure
Surge Pressure
Dense Phase Pressure
Guide Vane Position
Pres. at upstream of choke valve for Compressor discharge of 11 Mpa
LEARNINGS AND CONCLUSION

- **Quest is the first commercial scale CCS project in Canada**
  - Pace setter for other efforts to manage CO$_2$ footprint in Alberta
  - Abundant learnings for future projects

- **Key success factors**
  - Early and extensive stakeholder engagement
  - Use of proven technology

- **System optimization (fit for purpose) and integration are important to minimize life cycle cost**
  - HMU integration
  - Utilities integration
  - Capture optimization

- **Worth considering**
  - Capture ready HMU’s or CO2 producers
  - Improvements in compressor configuration
  - Early injectivity data
NEXT STEPS

- INTO ‘EXECUTE’ PHASE TO STARTUP IN 2015
- 2013 MAJOR ACTIVITIES:
  - COMPLETION OF DETAILED ENGINEERING
  - BEGIN MAJOR CONSTRUCTION END 2012 (MOD YARD WORK)
  - MAJOR EQUIPMENT DELIVERY AND SETTING ONSITE
  - MMV BASELINE DATA GATHERING
  - BEGIN OPERATIONS READINESS AND TRAINING
  - COMPLETION OF REGULATORY APPLICATIONS (PIPELINE LATERALS)
  - ONGOING STAKEHOLDER MANAGEMENT

September 19, 2013
23 PCCC2 Conference
**TOTAL COST OF QUEST - CDN$1.4 BILLION**
- INCLUDES PRE FID, CAPITAL AND 10 YEARS OPEX
- CAPITAL RATIO: 80% CAPTURE, 10% PIPELINE, 10% WELLS

**REVENUES - GHG OFFSETS (CREDITS)**
- NET AMOUNT - STORED CO2, LESS DIRECT AND INDIRECT EMISSIONS
- CREDITS TO BE USED FIRST BY SHELL’S ALBERTA ASSETS FOR REGULATORY COMPLIANCE

**GOVERNMENT FUNDING SUPPORT - CDN$865 MILLION**
- CDN$120 MILLION CANADIAN FEDERAL GOVERNMENT (PRE FID)
- CDN$ 745 MILLION ALBERTA PROVINCE (CONSTRUCTION, STARTUP AND 10 YEARS OPERATION)
- EXTENSIVE KNOWLEDGE SHARING
- STRINGENT MONITORING (MMV) PLAN
- NPV ZERO COMMITMENT
REGULATORY FRAMEWORK

PROVINCIAL GHG FRAMEWORK ESTABLISHED

- CCS ACT PASSED IN NOV 2010, ESTABLISHING OVERALL STRUCTURE
- PORE SPACE REGULATIONS IN PLACE WITH QUEST SUCCESSFULLY ACQUIRING REQUIRED AREA IN MAY 2011
- PARTICIPATION IN REGULATORY FRAMEWORK ASSURANCE (RFA) PROCESS AND GHG OFFSET PROTOCOL REVISIONS
- NO FEDERAL FRAMEWORK TO DATE – POSSIBLE 2013

REGULATORY APPROVALS NEAR COMPLETE

- FEDERAL COMPLIANCE ACHIEVED – EIA SUBMITTED, COMPLETED INTERNAL AND PUBLIC REVIEW
- BUNDLED PROVINCIAL APPLICATION SUBMITTED – UPGRADE AMENDMENT, PIPELINE, WELL AND STORAGE
- 3 ROUNDS OF INFORMATION REQUESTS (200+) BY PROVINCIAL REGULATOR, THE ERCB
- ERCB PUBLIC HEARING MARCH 2012
- SUMMER WORKS AND DRILLING PERMITS TO FOLLOW ERCB DECISION
GENERAL PROJECT ASSESSMENT

GENERAL ASSESSMENT - VERY POSITIVE

MAJOR PROJECT ATTRIBUTES (TECHNICAL, COSTS, REGULATORY, STAKEHOLDERS) TRACKING AS PLANNED

PROJECT SUCCESSES

GOVERNMENT FISCAL SUPPORT
PORE SPACE TENURE
CAPTURE AND PIPELINE FRONT END ENGINEERING AND DESIGN (FEED) COMPLETION AND ASSURANCE
TEST WELL AND AQUIFER PROPERTY VERIFICATION
STAKEHOLDER ENGAGEMENT
PIPELINE ROUTING FINALIZATION
DNV CERTIFICATION OF THE STORAGE DEVELOPMENT PLAN
REGULATORY HEARING

CHALLENGES

CAPITAL COSTS
SCHEDULE PRESSURE
REGULATORY UNCERTAINTY (GHG PROTOCOLS, FEDERAL FRAMEWORK)