Quest CCS Project

CSLF Technical Workshop, Abu Dhabi

Simon O’Brien
Quest Storage Manager
Definitions & cautionary note

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this presentation “Shell”, “Shell group” and “Royal Dutch Shell” are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words “we”, “us” and “our” are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. “Subsidiaries”, “Shell subsidiaries” and “Shell companies” as used in this presentation refer to companies over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as “joint ventures” and “joint operations” respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as “associates”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management’s current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management’s expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as “anticipate”, “believe”, “could”, “estimate”, “expect”, “goals”, “intend”, “may”, “objectives”, “outlook”, “plan”, “probably”, “project”, “risks”, “schedule”, “seek”, “should”, “target”, “will” and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell’s products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell’s Form 20-F for the year ended December 31, 2016 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this presentation and should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, May 2, 2017. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

We may have used certain terms, such as resources, in this presentation that United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. U.S. investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain this form from the SEC by calling 1-800-SEC-0330.
Towards a lower-carbon future

Shell is working to meet the energy challenge in many different ways.

- Bringing lower-carbon natural gas to a wider market
- Industry leader in carbon capture and storage
- A biofuels business
- Investment in lower-carbon technologies, such as hydrogen and wind power
- Continued investment in oil and gas to meet growing demand
- Advocating government-led carbon-pricing mechanisms
Shell Involvement in CCUS projects

- **Industrial scale projects in operation**
  - **Quest CCS**: 1 mtpa, Capture: amine, Shell operated
  - **Lula CCUS**: 0.7 mtpa, Capture: membrane, Petrobras operated, Shell is a JV partner
  - **TCM test centre**: up to 200 ktpa, Capture: various technologies, Shell is a JV partner and tests at TCM
  - **Peterhead CCS (cancelled)**: 10–15 million tonnes over the project’s lifetime, Capture: amine, Shell project developed with SSE through FEED but project cancelled
  - **Gorgon CCS**: up to 1 mtpa, Capture: amine, Shell is a JV partner

- **Industrialscale projects in construction**
  - **Boundary Dam**: between 3-4 mtpa, Capture: amine, Chevron operated, Shell is a JV partner

- **Planned but cancelled industrial scale project**
  - **Lula**

- **Involvement through Shell Cansolv technology – no Shell equity**

---

Copyright of Shell Canada

May 2017
Quest Project at a Glance

• **What** – fully integrated, commercial scale CCS project at an industrial facility

• **Where** – capture at Scotford Upgrader; storage in a deep saline aquifer: the Basal Cambrian Sands (at a depth of 2000m)

• **Who** – joint venture between Shell, Chevron and Marathon

• **Impact** – 25 million tonnes of CO₂ captured over a 25 year period (1/3 of CO₂ from the Upgrader) – equivalent to the emissions of about 250,000 cars

• **Technology** – syngas capture using amines
CO₂ Capture

- The Hydrogen Unit combines steam and natural gas to produce high pressure steam and H₂ for use in the upgrader.
- The Amine Unit uses Shell technology to capture the CO₂ directly from the process.
- The process produces a 99% pure CO₂ output.
- Award winning integrated, modular construction (Fluor).
Transport

• CO₂ dehydrated and compressed to >10 MPa to keep the CO₂ in dense phase through entire pipeline

• 65 km pipeline with 6 block valves (every 4-15 km)

• Pipeline construction Oct 2013 – Aug 2014, with over 30 re-routes to accommodate landowner requests

• Cleaning and preserved with nitrogen by October 2014

• First CO₂ into pipeline August 2015
Storage Facility

- 3 well pads: each pad has 1 injection well, 1 deep monitoring well and multiple shallow ground water wells

- Conventional drilling methods

- Multiple steel casings for injection wells, 3 in freshwater zone, all cemented to surface

- Comprehensive Measurement, Monitoring and Verification program
The Storage Complex

BCS Storage Complex

- Deep (~2km) saline aquifer
- Below potable water zones, zones with hydrocarbon potential
- Multiple thick, continuous seals (>150m within the complex)
- High quality (~17% porosity) sandstone reservoir
- Excellent permeability (~1000mD)

<table>
<thead>
<tr>
<th>Depth</th>
<th>Sedimentary Layer</th>
<th>Seal Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>85m</td>
<td>Prairie Evaporite</td>
<td>Additional Seal</td>
</tr>
<tr>
<td>85m</td>
<td>Upper Lotsberg Salt</td>
<td>Ultimate Seal</td>
</tr>
<tr>
<td>10m</td>
<td>Lower Lotsberg Salt</td>
<td>Secondary Seal</td>
</tr>
<tr>
<td>70m</td>
<td>Middle Cambrian Shale</td>
<td>Primary Seal</td>
</tr>
<tr>
<td>40m</td>
<td>Basal Cambrian Sand</td>
<td>Storage Reservoir</td>
</tr>
<tr>
<td>0</td>
<td>PreCambrian Shield</td>
<td></td>
</tr>
</tbody>
</table>
### Quest MMV Plan

<table>
<thead>
<tr>
<th>Atmosphere</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>LightSource Laser CO2 Monitoring</td>
<td>Eddy Covariance Flux Monitoring</td>
<td>?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biosphere</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Natural Tracer Monitoring</td>
<td>CO2 Flux and Soil Gas</td>
<td>Remote Sensing (Brine &amp; NDVI)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hydrosphere</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Groundwater Wells: Continuous EC, pH</td>
<td>Discrete Chemical and Isotopic Analysis on water and gas</td>
<td>Private Landowner Groundwater Wells (discrete chemistry and isotopes on water and gas)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geosphere</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-Lapse Walkaway VSP Surveys</td>
<td>Time-Lapse 3D Surface Seismic</td>
<td>InSAR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deep Monitoring Wells</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downhole Pressure &amp; Temperature (DHPT) above Storage Complex (CKLK Fm)</td>
<td>Downhole Microseismic Monitoring</td>
<td>?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injection Wells</th>
<th>Injection</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Rate Metering, RST Logging, Temperature logging</td>
<td>DHPT, Well Head PT, Distributed Temperature and Acoustic Sensing, Annulus Pressure Monitoring, Wellhead CO2 Sensor, Mechanical Well Integrity Testing, Operational Integrity Assurance</td>
<td>?</td>
</tr>
</tbody>
</table>

- First of a kind – conservative approach
- Comprehensive: from atmosphere to geosphere
- Risk-based
- Site-specific
- Independently reviewed
- Combination of new and traditional technologies
- Baseline data collected before start-up

Time (years): 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050
Quest – Startup

- Pipeline fill and testing completed quickly
- 8-19 and 7-11 wells started without incident
- 5-35 well held back as contingency
- Very smooth start-up
- Commercial Operations Certificate awarded in September, 2015
First 18 months Performance

Capture:
- 1 million tonnes in first year
- Operating costs lower than expected
- Exceeding expectations

MMV:
- MMV systems working well – no triggers
- Multiple technologies indicate that the CO₂ is where it is expected to be

Wells:
- Only 2 wells active – contributing to significant wells and MMV savings

Reservoir:
- Excellent injectivity – comparable to high case scenarios
- After 25 years, we only expect to use 5-7% of the available pore space
Quest Capture Learnings

- Compressor reverse rotation – ensure shutdown depressuring study based on installed arrangement
- Carbon steel in low pH water service – piping spec changes must be caught in design phase
- Filtration – foaming/ flooding in amine absorbers tied to carbon entrainment and throughput management
- **Existing HMU operating strategy** required modifications to operate reliably in Quest mode – successfully implemented
- **Below Budget Chemical Loss** – both TEG and amine
- **Reliability Beating Plan** – good design and operating strategies producing strong CO2 capture performance
Quest Storage Learnings

**MMV:**
- MMV systems working well – no triggers
- Microseismic array has been very quiet
- VSPs can image CO₂ in the BCS, DAS working well

**Wells:**
- Only 2 wells active – significant wells and savings
- Pulse neutron logging confirmed that CO₂ is where it is supposed to be
- Important to keep water out of the wells, even the small amounts routinely used during logging

**Reservoir:**
- Excellent injectivity – comparable to high case scenarios
- After 25 years, we expect to use 5-7% of the available pore space
- Current estimate is that the ΔP at the end of the project may only be 2 MPa.
Stakeholder Learnings

• The need to listen
  • Perceived risk can be as real and important as actual risk

• Hear concerns and accept them as legitimate
  • Be open to changing the plan to accommodate community feedback

• Meet stakeholders on their terms and where they are comfortable
  • Don’t expect them to come to you and then be surprised when they later raise objections

• Develop consistency and deep relationships
  • They may mistrust the organization, but they will trust people

• They want to get to know the leaders and the experts – not just community relations team
Acknowledgements

• Government of Alberta, Department of Energy (DOE)
• Government of Canada, Natural Resources Canada (NRCan)
• Shell staff (Calgary, Scotford, Houston, EU and in the field)
• Partners: Chevron Canada Ltd & Marathon Oil Canada