CCS – INNOVATION IN SHELL

INNOVATION IS BRINGING AN INSIGHTFUL IDEA SUCCESSFULLY TO THE MARKET

CLIMIT SUMMIT 2013
25th — 26th February

Oslo

Dr. Ir. Robert Moene
Teamlead CO₂ abatement – Projects & Technology Innovation
Resources: Our use of the term “resources” in this announcement includes quantities of oil and gas not yet classified as Securities and Exchange Commission of the United States (“SEC”) proved oil and gas reserves or SEC proven mining reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this announcement “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 announcement refer to companies in which Shell either directly or indirectly has control, by having either a majority of the voting rights or the right to exercise a controlling influence. The companies in which Shell has significant influence but not control are referred to as “associated companies” or “associates” and companies in which Shell has joint control are referred to as “jointly controlled entities”. In this announcement, associates and jointly controlled entities are also referred to as “equity-accounted investments”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect (for example, through our 23 per cent shareholding in Woodside Petroleum Ltd.) ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This announcement contains forward looking statements concerning the financial condition, results of operations and businesses of Shell and the Shell Group. 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 Shell and the Shell Group 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”, “seek”, “should”, “target”, “will” and similar terms and phrases. There are a number of factors that could affect the future operations of Shell and the Shell Group and could cause those results to differ materially from those expressed in the forward looking statements included in this announcement, 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. All forward looking statements contained in this announcement 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 factors that may affect future results are contained in Shell’s 20-F for the year ended 31 December 2011 (available at www.shell.com/investor and www.sec.gov ). These factors also should be considered by the reader. Each forward looking statement speaks only as of the date of this announcement, 07 November 2012. Neither Shell nor any of its subsidiaries nor the Shell Group 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 announcement.

Shell may have used certain terms, such as resources, in this announcement that the SEC strictly prohibits Shell from including in its filings with the SEC. U.S. investors are urged to consider closely the disclosure in Shell's Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain these forms from the SEC by calling 1-800-SEC-0330.
SHELL’S RESPONSE TO THE CO₂ CHALLENGE

Supplying More Natural Gas

Supplying More Biofuels

Progressing CCS

Energy Efficiency In Our Operations
Shell involvement in CCS Projects:

- **Blue** Industrial scale projects in operation
- **Red** Industrial scale projects in construction
- **Pink** Industrial scale projects planned
- **Light Pink** Demonstration projects, joint industry partnerships

- **Quest**
- **Weyburn Midale**
- **TCM**
- **Aberthaw**
- **Peterhead**
- **Boundary Dam**
- **Gorgon**
- **Otway**
Cleaner production

- CO₂ Technology Centre Mongstad (TCM)
- BIGCCS – Centre for environment-friendly energy research.
- EDECIDE (CLIMIT) – Human and Eco-toxological effects of CCS
- CO₂ Base (CLIMIT) – Establish a robust baseline for monitoring of environmental impact of CO2 storage.
- EXSIRA II (CLIMIT) - Experimental Study Investigating Risks of select Amine
- EFFORT - Energy Efficiency in Offshore O&G Production
- EOOS – Optimization of Electrical Energy production in Offshore Installations
- Environmental Aspects of EOR Chemicals
Develop technologies that are robust in a CO$_2$ constrained world

**Systems integration:**
- Utility integration, utility led designs
- CCS operability impact on production assets, fall back scenarios
- Integrated capture, transport and storage optimization of line ups

**Process integration:**
- Process energy optimization & integration, smart line ups
- Minimizing process footprint (solvent losses, waste, toxicity)
- High pressure separation & regeneration concepts

**Equipment**
- High efficiency contactors, heat exchangers and rotating equipment
- Low cost construction materials and equipment
- Low maintenance, high reliability equipment

**CO$_2$ separation**
- Adsorbents
- Solvents
- Membranes
- Hybrid solutions

**CCS value chain – utility – complex integration**

**CCS Process integration**

**Equipment selection & development**

**CO$_2$ separation principle**
Climbing the pyramid to commercial readiness

Exploratory
- Materials: MOF’s, Ionic liquids, Liquid crystals, Supported Amines;
- Methods: Cryogenic separation, Electrochemical separation

Proof of concept
- Biphasic solvents,
- Non-aqueous solvent
- Membrane absorption, Polymeric membranes

Pilot scale testing
- Blended alkanol amines,
- Amino acid salts
- Adsorbents
- Carbonate Slurry

Demo
- Solvent based process:
- Cansolv

Commercial
- TCM
- Cansolv – Wales

Reduction of:
- Energy use
- Capture costs
CAPTURE R&D IN SHELL: “POST-COMBUSTION”

Reduce Cost, Increase Energy Efficiency, Scale-up

Low Pressure (Flue gas)
Solvent Absorption

- Chemical solvent e.g. MEA

Full Scale - Under construction

- Cansolv – New Development

Shell: Large-scale demos i.e. CANSOLV
Saskpower in operation by 2013.

Breakthrough “Carbonate Slurry”

- Potassium carbonate base
- Crystallising & concentration of captured CO2
- Potential ~50% reduction in regeneration energy
- Potential intrinsic lower nitrosamines emissions (HSE)
Carbonate Slurry – 3rd Generation Post Comb. Technology

Development towards demonstration and deployment

- Bench-scale pilot plant, Shell Technology Center Amsterdam, Start-up Q4, 2010, several revamps
- Capacity of pilot plant max 25 kg/d CO₂
- Dimensions 10m x 1.5m x 6m (H x L x W)
- Absorber: 4m Sulzer Mellapak 500y packing
- Stripper: 3.2m Sulzer DX packing.

Chemistry
1. CO₂ (aq) + H₂O + CO₃²⁻ → 2 HCO₃⁻
2. K⁺⁺ HCO₃⁻ → KHCO₃ (↓, S)

An accelerator is used to enhance mass transfer of CO₂ to liquid phase
Carbonate Slurry – Process & Development

- Bench-scale pilot plant operational improvements (hardware & process control)
- Screening of alternative accelerators
- Development of electrolyte model (including precipitation) for target system
- Screening of crystallization behavior.
- Techno-economic evaluation (Capex & Opex)

**Energy Efficiency**
A precipitating process can combine a low steam strip and a low heat of reaction.

**NGCC-CCS**
Rich solvent loading and energy consumption hardly depend on pCO₂ owing to the solids concentration step.
Reduce Cost, Increase Energy Efficiency, Scale-up

High Pressure (Feed gas & Pre-combustion)

Solvent Absorption
- Chemical solvent e.g. ADIP-X
- Physical solvent e.g. Selexol™Chemical
- Hybrid solvent e.g. Sulfinol

Cryogenics Recovery of CO₂
- High Concentration, HP Feed Gas
- CO₂ separated from gases by cooling and condensation
- CO₂ capture in liquid for transport, injection and EOR

Membrane separation
- Palladium Membranes - CRI Development
- High purity hydrogen production (decarbonized fuel)
- High pressure CO₂ production → lower compression cost
**Successful Piloting at NCCC site**

1,700 hrs at 10ton CO\textsubscript{2}/day
(0.5MWe slipstream)

**Next Steps:**

- Demonstration campaign
  at RWE site, UK, 50ton CO\textsubscript{2}/day

- Commercialization
  (DC-201 to improve actual DC-103 offer)
### Timeline for Project Key Milestones

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Startup Combined SO$_2$/CO$_2$ Process</td>
<td>January 8, 2013</td>
</tr>
<tr>
<td>Familiarization Phase</td>
<td></td>
</tr>
<tr>
<td>Start of CANSOLV DC103 Testing Program</td>
<td>2013</td>
</tr>
<tr>
<td>End of DC103 Testing</td>
<td></td>
</tr>
<tr>
<td>New Generation Solvents Testing</td>
<td></td>
</tr>
<tr>
<td>Demonstration Project Completion</td>
<td>2014</td>
</tr>
</tbody>
</table>
Shell partner on TCM

- To develop technology enabling oil & gas as a sustainable energy source in the future.
- Ensure development of CO₂ capture technologies for future deployment within Shell.
- To increase our operational knowledge of CO₂ capture technology

TCM - One of the world’s most advanced test centres for CO₂ capture

TCM Objective

- Test, verify, demonstrate and qualify technology suitable for deployment of large scale CO₂ capture facilities.
- Reduce costs, technical, environmental and financial risks.
Shell/Cansolv and SSE are looking to develop the world’s first full-scale gas CCS project – the Peterhead Project.

Scotford Upgrader, Alberta in Canada, design capacity to process 255,000 BOE/d of diluted bitumen

First Quest CO$_2$ Injection Well
CO$_2$ transport from Upgrader through 80 kilometer underground pipeline to injection wells.
CCS COMMERCIALIZATION – SASKPOWER/CANSOLV

Full-scale with Shell technologies

- Location: Boundary Dam Power Station, Estevan, Saskatchewan, Canada
- Feedstock: Coal
- Size: 110 MW (1 mln ton CO₂/yr)
- Capture Technology: Post-combustion amine (including SO₂ capture)
- CO₂ Fate: EOR via 100 km pipeline