CO2 Geological Storage: Lesson Learned from In Salah (Algeria)

Iain Wright (CO2 Project Manager, BP Group Technology)

SBSTA Meeting Bonn May 20th 2006
Agenda

• CCS Benefits
• CCS Challenges
• The In Salah Project (Algeria)
  – How In Salah is addressing the challenges
• Summary
## Technology Options for Stabilization

### The Stabilisation Wedge

<table>
<thead>
<tr>
<th>Emission trajectory BAU</th>
<th>Emission trajectory to achieve 500ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1 GtC Slices of the Stabilisation Wedge

<table>
<thead>
<tr>
<th>Emissions (Gt Carbon)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2000</td>
</tr>
<tr>
<td>12</td>
<td>2010</td>
</tr>
<tr>
<td>10</td>
<td>2020</td>
</tr>
<tr>
<td>8</td>
<td>2030</td>
</tr>
<tr>
<td>6</td>
<td>2040</td>
</tr>
<tr>
<td>4</td>
<td>2050</td>
</tr>
</tbody>
</table>

### Examples of Lower Carbon Slices

<table>
<thead>
<tr>
<th>Description</th>
<th>Scale for 1 GtC Reduction by 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased <strong>energy efficiency</strong> across the economy</td>
<td>‘Emissions/$GDP’ increased</td>
</tr>
<tr>
<td>Increased <strong>energy efficiency</strong> (e.g. vehicles only)</td>
<td>2 billion gasoline/diesel cars achieving 60mpg</td>
</tr>
<tr>
<td><strong>Fuel switching</strong> natural gas displacing coal for power</td>
<td>1400CVW fuelled by gas instead of coal</td>
</tr>
<tr>
<td><strong>Solar PV or wind</strong> replaces coal for power</td>
<td>1000x scale up PV; 70x scale up for wind</td>
</tr>
<tr>
<td><strong>Biofuels to replace petroleum based fuels</strong></td>
<td>200x10^6 ha growing area (equals US agricultural land)</td>
</tr>
<tr>
<td><strong>Carbon Capture and Geological Storage</strong></td>
<td>CO₂ captured from 700 1 GW coal plants; storage = 3,500x In Salah/Sleipner</td>
</tr>
<tr>
<td><strong>Carbon Free Hydrogen for Transport</strong></td>
<td>1 billion H₂ carbon free cars; H₂ from fossil fuels with CO₂ capture &amp; storage or from renewables or nuclear</td>
</tr>
<tr>
<td><strong>Nuclear</strong> displaces coal for power</td>
<td>700 1 GW plants (2x current)</td>
</tr>
<tr>
<td><strong>Biosequestration in forests and soil</strong></td>
<td>Increase planted area and/or reduce deforestation</td>
</tr>
</tbody>
</table>
CCS 2006: Key Challenges

1. Reducing the Costs
   - Mainly Capture, Capital Cost and Efficiency
   - Target: $20-30/t CO$_2$

2. Is it Legal?
   - Long-term Storage Integrity
   - Legal & Regulatory Frameworks

3. Can you get Paid?
   - Policy Frameworks
   - Market Eligibility (CDM, ETS)

4. Public Acceptance

} In Salah CO$_2$
Joint Industry Project (JIP)
Three Projects at In Salah

- **In Salah Project(s) Overview**
  - In Salah Gas Development  (1bcf/d      $2,000 million)
  - In Salah CO$_2$ Storage   (1mmtpa       $   100 million)
  - In Salah CO$_2$ Assurance R&D (CSLF & EU $   30 million)
– In Salah Gas Development

• (1 bcf/d $2,000 million)
In Salah Gas Project

MAP: Locations and connections of the In Salah Gas Project in Algeria, showing the pipeline network and key locations such as Hassi R'Mel, In Salah, Gour Mahmoud, and others.

CO2 Emissions:
- <0.3% CO2 near Hassi R'Mel
- 5-10% CO2 near In Salah Gas Project

Key Points:
- Pipeline lengths and distances between sites:
  - 48" pipeline: 455 km
  - 38" pipeline: 60 km
  - 24" pipeline: 13 km, 62 km
- Map highlights the proposed ISG pipeline network and major gas fields in the area.
In Salah Gas Processing Plant

- Import Gas Pipeline from Teguentour and Reg
- Export Gas Pipeline to Hassi R’MEL & Europe (1 BCF/d)
- CO₂ Storage Pipeline to Krechba
- In Salah CO$_2$ Storage
  - 1mmtpa $100$ million
In Salah: 25-Year CO₂ Profile

- Only the separated (yellow) CO₂ will be stored – the combustion CO₂ (blue) will be vented
In Salah CO\textsubscript{2} Storage

- Industrial Scale Demonstration of CO\textsubscript{2} Geological Storage (Conventional Capture)
- Started Storage in August 2004
- 1mmtpa CO\textsubscript{2} Stored (17mm tonnes lifetime)
- $100mm Incremental Cost ($6/tCO2)
  - No Commercial Benefit
- Test-bed for CO\textsubscript{2} Monitoring Technologies
In Salah CO\textsubscript{2} Storage Operation

- Carboniferous Reservoir - 20 metres thick
- Carboniferous Mudstones - 950 metres thick (Regional Aquifer)
- Cretaceous Sandstones & Mudstones - 900 metres thick

- 4 Gas Production Wells
- 3 CO\textsubscript{2} Injection Wells

Amine CO\textsubscript{2} Removal

Processing Facilities
Krechba Field

Reservoir

Injectors

Producers

First Gas Development Well Locations

Gas-Water Contact

Spheroid: Clarke 1880
Projection: UTM Zone 31N
Datum: N Sahara 1959

0 5000 Meters

1330 metres below Mean Sea Level
~1800 metres below Ground Level

Kb-7
Kb-10
Kb-CA
Kb-6
Kb-CE
Kb-501
Kb-1
Kb-503
Kb-502
Kb-501
Kb-11
Kb-12
Kb-13
Kb-5
Kb-9z
Kb-8
Kb-4
Kb-2

Full Gas Column

First Gas Development Well Locations

Reservoir Surface
CO2 Storage Infrastructure

50mmScf/d CO$_2$ (1mmtpa)
Compression
Transportation
Injection
Storage
Power Plant with CCS
– In Salah CO$_2$ Assurance

• R&D (CSLF $30$ million)
Objectives (2004-09)

1. Provide assurance that secure geological storage of CO$_2$ can be cost-effectively verified and that long-term assurance can be provided by short-term monitoring.

2. Demonstrate to stakeholders that industrial-scale geological storage of CO$_2$ is a viable GHG mitigation option.

3. Set precedents for the regulation and verification of the geological storage of CO$_2$, allowing eligibility for GHG credits
Why Monitoring?

- Need more cost-effective tools to demonstrate long-term storage integrity
- Oil & Gas Industry already has most of the tools required, but has never had a commercial reason to develop them
- Mother Nature made all geological formations different
  - Monitoring technology that works in one location may not work in another
  - Need to develop a pool of knowledge
  - Need to set standards for site certification
<table>
<thead>
<tr>
<th>Technology</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>4D Seismic/VSP</td>
<td>Programme recommended – KEY TECHNOLOGY</td>
</tr>
<tr>
<td>4D Gravity</td>
<td>Modelling completed – marginal response</td>
</tr>
<tr>
<td>Tracers</td>
<td>Due to commence 1Q2006</td>
</tr>
<tr>
<td>4D Electrical/EM</td>
<td>Initial modelling suggests no response</td>
</tr>
<tr>
<td>Dynamic modelling</td>
<td>Building new model in Eclipse</td>
</tr>
<tr>
<td>Flow meter surveys</td>
<td>Reviewed and Not Recommended</td>
</tr>
<tr>
<td>Wellhead CO₂ Monitoring</td>
<td>Sampling programme ongoing</td>
</tr>
<tr>
<td>Formation water chem.</td>
<td>Analyses incorporated in Shared Earth Model</td>
</tr>
<tr>
<td>Injection monitoring</td>
<td>Ongoing by JV</td>
</tr>
<tr>
<td>Rock-fluid/Pressure Interactions</td>
<td>Studies ongoing in Norway</td>
</tr>
<tr>
<td>Specialist CO₂ modelling</td>
<td>Part of geochemistry studies ongoing in Norway</td>
</tr>
<tr>
<td>Microseismic</td>
<td>Programme recommended- awaiting info on access to suspended wells</td>
</tr>
</tbody>
</table>
Seismic Array Location

First Gas Development Well Locations

0 5000 Meters
Kb-7
Kb-10
Kb-CC
Kb-6
Kb-CE
Kb-1
Kb-501
Kb-1
Kb-503
Kb-9z
Kb-8
Kb-4
Kb-2

Gas-Water Contact
1330 metres below Mean Sea Level
1800 metres below Ground Level

Full Gas Column

Kb-502
Kb-14
Kb-11
Kb-12
Kb-13
Pre-cursor 3D

Spheroid: Clarke 1880
Projection: UTM Zone 31N
Datum: N Sahara 1959
In Salah CO₂ Summary

- Industrial Scale Demonstration of CO₂ Geological Storage (Conventional Capture)
- Excellent Analogue for other Countries:
  - China, Europe, North America
- Started Storage in August 2004
- 1mmtpa CO₂ Stored (17mm tonnes lifetime)
- $100mm Incremental Cost for Storage ($6/tCO₂)
  - No commercial benefit
- Test-bed for CO₂ Monitoring Technologies
  - $30mm Research Project