CO₂ Geological Storage: Principles and Application to Field Projects

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Presentation Outline

Introduction
- Climate Change Science
- Magnitude of Mitigation
- CO₂ Capture, Transportation and Geologic Storage*

CO₂ Geologic Storage
- Venues & Capacity
- Technology

Geologic Storage Projects
- Commercial
- Planned (Gorgon)

Outlook for CO₂ Capture and Storage

For Further Information...

*Nomenclature: CO₂ Sequestration = CO₂ Capture, Transportation and Storage
Introduction – Climate Change Science

Inter-governmental Panel on Climate Change (IPCC) - Third Assessment Report [TAR] (2001) Scenario Projections for 2100:

- 500-900 ppm atm. CO_2*
- +1.6-6.2°C Temp. Incr.
- 0.2-0.7m Sea level Rise
- Extreme weather patterns / events; extinctions & habitat changes; etc.

* Pre-Industrial ~280ppm; Present ~380ppm (+1.5/yr.)
Introduction – Magnitude of Mitigation

No technology improvement – rapid growth in GHG levels to meet development needs

With significant technology improvement, development still drives GHG levels up.
- Fossil fuels improvements
  - Energy intensity
  - Nuclear
  - Renewables

New technologies will be needed if stabilization is desired.
- H2 and Adv. Transportation
- Biotechnologies (Soils, Bioenergy)
- Carbon capture & disposal

Edmonds, PNNL, 2003
“Low hanging fruit” includes gas processing, chemical & H₂ plants

Post-combustion, pre-combustion and oxy-firing (in order of present technical development) projected at US$40-60/tonne CO₂

Costs vary considerably based on transport distance and compression needs
Geologic CO₂ Storage – Venue Types

Overview of Geological Storage Options
1. Depleted oil and gas reservoirs
2. Use of CO₂ in enhanced oil and gas recovery
3. Deep saline formations — (a) offshore (b) onshore
4. Use of CO₂ in enhanced coal bed methane recovery

Courtesy CO2CRC
# CO\textsubscript{2} Storage – Capacity & Feasibility

<table>
<thead>
<tr>
<th>Major Storage Venues</th>
<th>Capacity (GtCO\textsubscript{2})*</th>
<th>Major Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural &amp; Enhanced Sinks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oceans</td>
<td>Huge</td>
<td>Politically Infeasible</td>
</tr>
<tr>
<td>Forests</td>
<td>?</td>
<td>Permanence, Accounting</td>
</tr>
<tr>
<td>Soil Mgmt.</td>
<td>?</td>
<td>Permanence, Accounting</td>
</tr>
<tr>
<td>Mineral Reactions</td>
<td>?</td>
<td>Kinetics, Materials</td>
</tr>
</tbody>
</table>

| **Geological Storage****          |                                     |                                                  |
| Depleted O&G Fields               | 450                                 | Well Leakage; Phase Interactions                 |
| Coal Beds                         | 60-150                              | Complexity, Injectivity                         |
| Saline Formations                 | 300-10000                           | Characterization, Closure?                      |

*Perspective*

- UN IPCC SRCCS – at least 2,000 GtCO\textsubscript{2} potential “likely” (66-99% CI) for geologic storage
- 25 GtCO\textsubscript{2}/PA presently emitted globally
- 0.02 GtCO\textsubscript{2}/PA injected into 50 W. TX fields for EOR (n.b., recycle)

*Data from Stevens et al. 1999, 2001; IEA GHG R&D Program*
Geologic CO₂ Storage – Distribution of Venues

Data from Dooley et al. (2004)
Geologic CO$_2$ Storage – Status of Technology (CO$_2$ Capture Project [CCP])

**System Integrity**
- Geologic
- Engineered (Wells)

**Optimization**
- HC fluid interactions
- Injection Strategies
- Reservoir Simulation

**Monitoring**
- Imaging
- Leakage to Surface

**Risk Assessment**
- Methodologies
- Communication

Readiness:
*Advanced/Adequate/Needs Attention*

Crystal Geyser Utah (Utah St U)

Injection Simulation (U Texas)

Sub-Surface Imaging (LBNL)
Geologic CO₂ Storage – Commercial Projects (Operating and Planned by Type)
Commercial Projects – Sleipner (Nor. North Sea)

First “Commercial” Purpose – Built CO₂ Storage Project

Operated by Statoil with injection of ~ 1MtCO₂PA since 1996

- Avoid Norwegian (first) carbon tax
- Offshore processing of 9% CO₂ Sleipner Gas (sales) via amine separation
- Utsira saline formation very high permeability, unconsolidated

Repeat 3D seismic shows “no” leakage
Commercial Projects – Weyburn (SK, Canada)

CO₂ EOR-“Storage” Project

- Operated by EnCana since 2001 to revitalize 50 yr. old field
- > 1.5 MtCO₂PA injected into carbonate reservoir
- Anthropogenic source (lignite gasification in N.D.)

Extensive R&D Program (JIP)

- Geologic Modeling
- Repeat Seismic
- Reservoir Simulation
- Geochemistry
- Risk Assessment
Commercial Projects – In Salah (C. Algeria)

Operated by BP (w/ Statoil & Sonatrach) since 2004

Process Gas for Export (9% CO₂)

1 MtCO₂PA into water leg of gas reservoir (Cumm. ~17MtCO₂)

EU-Funded “Assurance” JIP

 Courtesy BP, Sonatrach & Statoil
Commercial Projects (Planned) – Gorgon (NW Australia)

Process Gas (14% CO₂) for LNG
Operated by Chevron
- 25% ExxonMobil / 25% Shell
- Co-development of Jansz
First gas with CO₂ separation & injection in 2010 if “technically and economically feasible”

Dupuy Saline Formation Target
- “Optimal” site in region
- Onshore Barrow Island (Class A Nature Reserve)
- Overburden includes thick saline formation and regional seals

GHG Reductions
- Process efficiencies
- ~2.7 MtCO₂PA (cumm. ~130)
Commercial Projects (Planned) – Gorgon (NW Australia) – cont.

Development Plan – 7 injectors from 2 centers

Permeability Distribution Prevents Rapid Vertical Migration

Pressure Field Peaks at ~30 yr.

Major Mechanisms Likely to Immobilize Most CO₂ Within 1000 yr.

Aerial Extent of Plume Increases Slowly After 40 yr. (Operational Phase)

Security of CO₂ Storage

O&G Industry has Decades Long Experience in Processing, Transporting & Injecting Gases

Multiple Trapping Mechanisms

Injection Strategies

UN-IPCC SRCCS Consensus:

- “Very likely” (90-99% CI) to exceed 99% over 100 yr.
- “Likely” (66-90% CI to exceed 99% over 1000 yr.

Intervention Options Available

Challenges: Well Integrity, Certification and Communication
CCS Role in GHG Mitigation

UN-IPCC SRCCS
## Existing & Planned “Commercial” CCS Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator</th>
<th>Date</th>
<th>Location</th>
<th>Source</th>
<th>Sink</th>
<th>MTPA</th>
<th>Sum</th>
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</thead>
<tbody>
<tr>
<td>Sleipner</td>
<td>Statoil</td>
<td>1996</td>
<td>Nor. North Sea</td>
<td>Gas Proc. (Sales)</td>
<td>Sal. Fm.</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Weyburn</td>
<td>Encana</td>
<td>2001</td>
<td>Canada (SK)</td>
<td>Power (Coal)</td>
<td>EOR</td>
<td>2.0</td>
<td>3.0</td>
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<tr>
<td>In Salah</td>
<td>BP</td>
<td>2004</td>
<td>C. Algeria</td>
<td>Gas Proc. (Sales)</td>
<td>Sal. Fm.</td>
<td>1.0</td>
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<td>Snohvit</td>
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<td>Nor. Barents Sea</td>
<td>Gas Proc. (LNG)</td>
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<td>Gorgon</td>
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<td>Gas Proc. (LNG)</td>
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<td>White Tiger-1</td>
<td>MHI</td>
<td>2010</td>
<td>Vietnam</td>
<td>Power (Gas)</td>
<td>EOR</td>
<td>3.0</td>
<td>10.8</td>
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<tr>
<td>Miller</td>
<td>BP</td>
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<td>UK North Sea</td>
<td>Refining (H2)</td>
<td>EOR</td>
<td>1.3</td>
<td>12.1</td>
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<td>Tangguh</td>
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<td>Indonesia</td>
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<td>Edison</td>
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<td>USA (CA)</td>
<td>Power (Pet coke)</td>
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<td>4.0</td>
<td>18.1</td>
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<td>Tjeldbergodden</td>
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<td>2011</td>
<td>Nor. North Sea</td>
<td>Power (Gas)</td>
<td>EOR</td>
<td>2.5</td>
<td>20.6</td>
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<td>&quot;Germany&quot;</td>
<td>RWE</td>
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<td>Germany</td>
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<td>TBA</td>
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<td>&quot;UK&quot;</td>
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<td>52.1</td>
</tr>
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</table>
Future, De-Carbonized Energy Concept
Thank You

For Further Information...

Inter-Government Organizations

- United Nations Intergovernmental Panel on Climate Change (UN-IPCC): www.ipcc.ch


Industry Organizations


- International Petroleum Industry Environmental Environmental Conservation Association (IPIECA) www.ipieca.org