Demonstration projects in Europe

SITES OUTSIDE EUROPE

- Canada (Weyburn, start 2000, EOR, 1.5 Mt/y)
- Australia (Gorgon (start 2009, Aquifer+gasss/shale, 2500 m, 5Mton/yr )
- USA (Frio, Tea Pot Dome, Lost Hills)
- Japan (aquifer and ECBM)
K12-B: tracking the plume ...

Courtesy GdF-TNO
Tracking the plume

1,3-PDMCH
PMCP

Courtesy GdF-TNO
Well integrity ...

Courtesy GdF-TNO

Rob Arts
Sleipner …
Sleipner ...
Reservoir characteristics:
Log panel (W-E, 20 km)

Courtesy CO2STORE
What does such a reservoir look like…

turbidite sandstones with thin (<1m) shale layers

turbidite sandstones with thick (~2m) shale layer
Tracking the plume ....

1994

1999

2001

2002

2004

2006

3 km

S

N

Courtesy CO2STORE
From seismic to simulation …. Predictions …

Real data → Synthetic convolution data → Synthetic FD after processing

3 km NS

Eindhoven, April 1, 2010

Courtesy CO2STORE
Combinations of data used as a constraint …

Gravity benchmarks

Size of CO₂ bubble 2001

Courtesy CO2STORE
Per station 3 gravimeters and 3 pressure gauges put on a fixed concrete benchmark
Tool to detect leakage … No leakage at Sleipner

- 8.4 million tonnes injected in period 1996-2006
- Area of CO₂ plume: 2.8 km²
- Length of CO₂ plume: 3760 m

1994


2006

200 ms

2 km

Rob Arts

Courtesy CO2STORE

Eindhoven, April 1, 2010
In Salah (Algeria)

Production Well Locations

First Gas Development Well Locations

Gas-Water Contact

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

Full Gas Column

4200
4300
3210
3220
3230

CO₂ Injectors

Gas Producers

CO₂ is reinjected into the reservoir at Krechba for long term sequestration

Cretaceous sandstones and mudstones – 900m thick

Four gas production wells

Carboniferous mudstones – 950m thick

Carboniferous reservoir around 20m thick

Gas zone

Water zone

Courtesy BP
Surface deformation at Krechba

Increased importance of:
- Microseismic
- Satellite imagery
- Tiltmeters

Surface deformation at Krechba

Up to 5mm relative uplift

~2mm relative subsidence

 Courtesy CO2REMOVE project
Snohvit – lay-out

- Well templates on seabed
- Controlled from land
- Multiphase transport in pipeline to land
- LNG plant onshore
- Separation of CO₂
- Re-injection

Courtesy Statoil
The reservoir

700,000 tons CO$_2$/year

Totally 23 mill tons

= 35 mill res. m$^3$
ECBM-pilot in Poland
Injection in coals (ECBM)

- capillary pressures
- 2-phase diffusion/convection

Courtesy Delft University of Technology
Storage in coals: Kaniow site (Poland)
In summary …

3 major industrial storage sites
~1 Mt CO₂/year

Sleipner
Snøhvit
In Salah

Laboratory-scale site
Ketzin

Kaniow

Smaller industrial storage site
K12-B

Photos courtesy: BP, Statoil, Sonatrach, GFZ, Sintef,
CO₂ flux – calculated values: Latera

- Total CO₂ flux is 7.7 k tonnes / year

<table>
<thead>
<tr>
<th>site</th>
<th>CO₂ flux (tonnes/day)</th>
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<tr>
<td>1</td>
<td>6.60</td>
</tr>
<tr>
<td>2</td>
<td>0.09</td>
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<tr>
<td>3</td>
<td>0.15</td>
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<tr>
<td>4</td>
<td>6.47</td>
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<tr>
<td>5</td>
<td>0.07</td>
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<td>7</td>
<td>0.20</td>
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<tr>
<td>8</td>
<td>7.54</td>
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<tr>
<td>total</td>
<td>21.15</td>
</tr>
</tbody>
</table>

3 locations account for 97.5% of CO₂ flux
Main CO$_2$ vents
Contents

• Introduction: Why CCS?
• Current status of regulations: The EU-directive
• The principles of underground CO$_2$ storage
• Current demonstration projects
• The potential for the Netherlands
• Closing remarks
Depleted Gasfields (GESTCO, 2003)

- Total capacity
  - 3400 Mt Non-Groningen
    - 2140 Mt onshore
    - 1260 Mt offshore
  - 7512 Mt Groningen
  - 206 fields < 4 Mt

-120 Mt ivm UGS in Alkmaar/ Grijpskerk/ Norg
Depleted Gasfields - Timing

- Groningen (7550 MT) released after 2040

After Breunese, 2006

- Groningen (7550 MT) released after 2040
Depleted Oilfields-EOR

- Schoonebeek: 19 MT
- F03: 9 MT
- L05: 7 MT
- Helder: 5 MT
- Totaal 40 MT
- 48 Velden < 4 MT
Saline Aquifers

- Onshore based on traps (cato project)
  - Storage efficiency: 405 MT
  - Onshore open aquifers: >5 GT (CCC project)

- Offshore (no detailed mapping):
  - Storage capacity: few 100’s Mt
  - Total open aquifers: > 5 GT?
Coals

- ECBM options in NL
  - Zeeland-Brabant: 220-260 MT*
  - Zuid Limburg: 8 MT
  - Peel: 14-18 MT
  - Achterhoek e.o: 56-210 MT*
  - Totaal: 298-496 MT

- * most of it > 1500 m

- Application not mature yet:
  - Uncertainty in capacity
  - Unknown permeability -> injectivity
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Closing remarks …

• CO2 storage is already being done for about 15 years in demo projects

• Regulations for CCS are currently being implemented

• The Netherlands have a unique storage potential due to the depleted gasfields