Challenges for onshore CO$_2$ storage

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Question

Why is there reluctance against deploying onshore CO$_2$ storage?

• Technical issues (?)

• Safety issues (?)

• Conflict of interest (?) – natural gas storage, geothermal energy production, hydrocarbon production etc...

• Public acceptance – NIMBY (Not In My BackYard) (?)

• Political and national climate and energy strategies (?) (CCS as an transition technology)
Pros and cons for onshore CO$_2$ storage compared to offshore

- Short distance between emission sources and sinks
- Operational “accessibility”
- Measures
  - Monitoring
  - Mitigation
- 3D/4D seismic surveys
- NIMBY (Not In My BackYard)
  - Dense population – potentially hazardous leakages(!)
  - Public awareness (and lack of acceptance)
CO₂ emission sources
Clustered CO$_2$ emission sources

CO$_2$ emission, Mt/year
- 0.05 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- 20.0 - 40.0
- 40.0 - 100.0
Pipelines

- Red: Gas
- Orange: Oil
- Green: Other
- Gray: No Data
- Light Gray: GeoCapacity countries
Geological potential for CCS
### CO2 density changes with increasing depth

![CO2 density changes with increasing depth graph](image)

### Key geological indicators for storage site suitability

<table>
<thead>
<tr>
<th>Reservoir Properties</th>
<th>Positive Indicators</th>
<th>Cautionary Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>&gt;800 m, &lt;2500 m</td>
<td>&lt;800 m, &gt;2500 m</td>
</tr>
<tr>
<td>Reservoir thickness</td>
<td>&gt;50 m</td>
<td>&lt;20 m</td>
</tr>
<tr>
<td>Porosity</td>
<td>&gt;20%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Permeability</td>
<td>&gt;500 mD</td>
<td>&lt;200 mD</td>
</tr>
<tr>
<td>Salinity</td>
<td>&gt;100 gl⁻¹</td>
<td>&lt;30 gl⁻¹</td>
</tr>
<tr>
<td>Stratigraphy</td>
<td>Uniform</td>
<td>Complex lateral variation and complex connectivity of reservoir facies</td>
</tr>
<tr>
<td>Capacity</td>
<td>Estimated effective capacity much larger than total amount of CO₂ to be injected</td>
<td>Estimated effective capacity similar to total amount of CO₂ to be injected</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Caprock Properties</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Lateral continuity</td>
<td>Stratigraphically uniform, small or no faults</td>
<td>Lateral variations, medium to large faults</td>
</tr>
<tr>
<td>Thickness</td>
<td>&gt;100 m</td>
<td>&lt;20 m</td>
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</tbody>
</table>

Chadwick et al., 2008
Storage options

Deep saline aquifers
- Large storage capacity
- Relative un-exploited geology with uncertainty in reservoir properties and storage security

Oil and gas fields
- Limited storage capacity
- Well-known geology and proven capability to accumulate gas
- Possibility for enhanced oil/gas recovery (EOR/EGR)
- Forecasts with history matched reservoir models
## Conservative capacity estimates (GeoCapacity)

<table>
<thead>
<tr>
<th>Country</th>
<th>Annual total CO₂ emissions (Mt)</th>
<th>Annual CO₂ emissions from large point sources (Mt)</th>
<th>CO₂ storage capacity in deep saline aquifers (Mt)</th>
<th>CO₂ storage capacity in hydrocarbon fields (Mt)</th>
<th>CO₂ storage capacity in coal fields (Mt)</th>
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<td>1761</td>
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<td>58</td>
<td>499</td>
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<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td><strong>1893</strong></td>
<td><strong>95724</strong></td>
<td><strong>20222</strong></td>
<td><strong>1089</strong></td>
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</table>

\[\sim 116 \text{ Gt} / \sim 2 \text{ Gt/y} = \sim 60 \text{ y}\]
GeoCapacity – onshore vs. offshore

- Offshore: 68%
- Onshore: 32%
Technical and safety issues (onshore CO₂ storage)

• 90+ years of natural gas storage (US, Canada and EU)

• Only 10 out of approx. 600 (40 aquifers) sites have experienced (detectable) leakage
  - Wellbore integrity
  - Caprock issues

• CO₂ - and natural gas storage similar issues
  - Leakage of injected gas
  - Monitoring gas plume migration
  - Risk management
  - Integrity of caprock
  - Aquifer and trap configuration
Storage complex (EC directive definition)
Vedsted site, onshore Denmark (conflict of interests)

No water production

Water production

Use of Vedsted site

CCS:
Store CO\textsubscript{2} from ~ 400 MW plant for (40+ years)

Geothermal energy:
Produce ~ 20 MW for district heating
Public acceptance and national energy strategies

CGS Europe study on the implementation and transposition process for the CCS-EC directive; can give some insight in to the different arguments for not deploying (onshore) CCS

- No direct technical issues reported – all imbedded in public awareness and perception of CCS, negatively influenced by some NGO’s

- In Denmark and Germany relative mature industrial size pilot projects (onshore) were abandoned – due to public resistance
Public acceptance and national energy strategies, con’t..

- Conflict of interests (may be mitigated by proper reservoir management)
  - Hydrocarbon fields
  - Geothermal energy production
  - Natural gas storage
  - Fresh water
  - Minerals and other resources

- CCS not part of the official national energy policy

- On-going public and political debate – CCS issues not resolved

- CO₂ EOR (enhanced oil recovery) is OK in most of the countries
Summary

No alarming technical difficulties to Onshore CCS compared to offshore

• Trapping mechanisms similar to offshore

• Potential leakage pathways
  - Well integrity, good control from Oil & Gas
  - Trap configuration, good control from Oil & Gas
  - Caprock issues, needs extra investigation for CCS (use experience from natural gas storage)

Technical issues can be resolved – onshore and offshore
Summary con’t ...

Public and political issues

• National climate and energy strategy,
  - CO$_2$ emission reduction target
  - Energy mix - renewables
  - Geology (insufficient capacity)
  - climate changes are global(!)

• Public perception of CCS
  - Better public awareness of what CCS really are
  - Transparent information
  - Use experiences from the natural gas storage industry
Thank you for your attention
EU co-financed CO₂ storage capacity projects

- **Joule II** finalised 1993
  The joule II project: The underground disposal of carbon dioxide
  All Europe

- **GESTCO** finalised 2003
  Geological Storage of CO₂ from Combustion of Fossil Fuel
  Belgium, Denmark, France, Germany, Greece, Netherlands, Norway, UK

- **Castor** (WP 1.2) finalised 2006
  Bulgaria, Croatia, Czech Rep., Hungary, Poland, Romania, Slovakia, Slovenia

- **GeoCapacity** finalised 2008
  Assessing European Capacity for Geological Storage of Carbon Dioxide
  Bulgaria, Croatia, Czech Rep., Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, UK, Bosnia-Herzegovina, Albania, FYROM, Luxembourg, Belgium, Norway
Vedsted-1 (P&A 1958)

Danish Energy Authority P&A open-hole well