Subsurface monitoring aspects of CO₂ storage in a saline aquifer
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Overview

- “5/42” store characterisation & modelling
- Aspects of MMV (measurement monitoring and verification)
  - Need to demonstrate that the injected CO$_2$ is contained within the geological store during and after injection
  - 4D seismic feasibility
  - Microseismic feasibility
- Conclusions
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Characterisation of 5/42

- 2010-12 Regional screening studies
- 2012-15 Detailed characterisation of 5/42
  - 2013 NGC drilled & tested UK’s first dedicated Carbon Capture & Storage appraisal well, 42/25d-3 funded by EEPR & ETI
  - Extensive log, core and testing programme – DEVEX 2014
5/42 Top Bunter Depth Surface

Massive saline aquifer in Bunter Sandstone of UK SNS

200 – 250 m thick
>1000 m deep

Phi – 15-25%
K – 10-1000mD

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Data Acquisition in 42/25d-3
(presented at DEVEX 2014)

The most comprehensive data gathering program in a UK well for years
Modelling of 5/42

Plan for First Load is injection of 2.68 Mt/yr for 20 years. Reservoir models predict CO₂ moves to structural crest

Seal provided by Haisborough Gp halites / shales

Injection downdip within Bunter Sandstone

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  - 4D seismic feasibility
  - Microseismic feasibility
- Conclusions
**MMV objectives**

- Need to demonstrate through monitoring that the injected CO$_2$ is contained within the geological store during and after injection
- Comparison of actual vs modelled CO$_2$ plume migration
- Verification of well and reservoir integrity
- Metering of injected CO$_2$ & permanent in-well monitoring (e.g. pressure, temperature) for injectivity
- Campaigns of geophysical monitoring, well logging
## Monitoring technologies screening

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<th>Installation / Baseline Cost</th>
<th>Maintenance Repeat Cost</th>
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4D seismic feasibility through modelling

Static/dynamic reservoir model

PEM 1. Used log-derived regressions and Gassmann equations to compute Porosity/NTG/Saturation changes to elastic properties

PEM 2. Laboratory acoustic travel time testing, cycling over pore pressure to derive pressure change effects on elastic properties
4D seismic feasibility – Pressure change effects

PEM 2. Laboratory acoustic travel time testing, cycling over pore pressure to derive pressure change effects on elastic properties

FracTech Laboratories

42/25d-3 core plugs
4D seismic feasibility
Can AVO separate out pressure & saturation effects?

EEI sensitivity to Pressure/Saturation from logs

EEI_S = AI(cos\(\chi\)) + GI(sin\(\chi\))

Por NTG Sat1 Sat2
Press1 Press2

Petro-Elastic Model

Vp/Vs/Rho1 Vp/Vs/Rho2

Syn1 Syn2

Syn(2-1)
4D dynamic modelling
Saturation and Pressure after 20 years

Saturation

Pressure

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4D seismic modelling Saturation, Pressure, Impedance

Saturation

Pressure

After 20 years

EEI_S

AI

EEI_P
4D seismic modelling Saturation, Pressure, Synthetics

Saturation

Pressure

After 20 years

Syn_EEI_S(20-0)  Syn_AI(20-0)  Syn_EEI_P(20-0)
4D seismic modelling
highlighting pressure signal relaxation

Syn_EEI_S(n-0)  Syn_AI(n-0)  Syn_EEI_P(n-0)

At end of injection

5 years after end of injection
Conclusions on Time-lapse seismic

- High amplitude sensitivity to modelled saturation changes
  - Large seismic contrast between CO₂ and brine in pore space
- Low amplitude sensitivity to modelled pressure changes
  - Open system, large aquifer

- Time-lapse seismic is an effective tool for monitoring CO₂ plume migration
Microseismic addresses MMV objectives

- Need to demonstrate through monitoring that the injected CO$_2$ is contained within the geological store during and after injection
- Comparison of actual vs modelled CO$_2$ plume migration
- Verification of well and reservoir integrity
Microseismic

- Feasibility study
  - Wavefields
  - Sensitivity
  - Location accuracy

After 430ms

Seabed detectors

Velocity profile

Depth (m)

Distance (m)

Microseismic event
Microseismic

- Feasibility study
  - Wavefields
  - Sensitivity
  - Location accuracy

- Seabed array would have sensitivity to events > -1.1 magnitude at Top Bunter in area of interest

- (-2–0 is nano event, length scale 1-10m, displacement 40-400 µm)
Conclusions & Discussion

- Requirement of a MMV plan is to demonstrate that
  - Injected CO\textsubscript{2} is contained within the geological store
  - During and after injection
- Comparison of actual vs modelled CO\textsubscript{2} migration – 4D
- Verification of well and reservoir integrity - Microseismic
- Longer timelines than typical N Sea projects
- Importance of acquiring baseline data
  - e.g. baseline 2D/3D seismic; background seismicity
- MMV plan is reviewed annually in light of data acquired
Acknowledgements

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- Tim Wynn, Scott Dingwall & Simon Wright
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Thanks & Questions