The CO2CRC/CSLF Otway Project

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www.co2crc.com.au
Supporters and Participants in this CSLF Endorsed Project

Established & supported under the Australian Government's Cooperative Research Centres Program
What is CO2CRC?

CO2CRC is a globally unique entity

- Integrates CCS R&D
- Addresses capture and storage and systems integration
- Brings industry sectors together (coal, gas, power, etc) to provide an exceptional stakeholder base
- Brings together Commonwealth, States, local government and the community in the Otway Project
- Includes major research institutions - CSIRO, Geoscience Australia, Universities, major overseas institutions
- Scale and focus – we bring together over 100 leading researchers in CCS
- Broad international perspective and experience
What has CO2CRC achieved?

• Australia’s first demonstration CO₂ storage project
• Australia’s largest, most comprehensive post-combustion capture research facilities
• Australia’s first pre-combustion capture facility
• Large number of research projects completed
• Critical input into framework for CCS legislation
• Contributor to international CCS activities such as the IPCC, the IEA GHG Program, CSLF
• Major source of information on CCS
• Provider of educational material and students trained in CCS
• Patents lodged for CCS technologies
• Very successful relationships with SMEs
Key achievements – CO2CRC Otway Project

Australia’s first demonstration CO₂ storage project

World class research facility that has safely stored 60,000 t of CO₂, with wide community support
Sealing Faults in the vicinity of the CO2CRC Otway Project

Source of CO2

Depleted gas field
CO2CRC Otway Project facilities

Buttress Site: CO2 production well (Buttress-1) & Surface Plant

Air Monitoring Site: Lo-Flo & Flux Tower

CRC-1 Site: Injection well (CRC-1)

CO2CRC Visitor’s Centre

Naylor-1 Site: Monitoring well (Naylor-1)

Pipeline
CO2CRC Otway Project
Schematic Stratigraphic Column of Otway Basin

KEY

I PHASE I INJECTION
II PHASE II INJECTION

SEAL
RESERVOIR

SHALLOW FORMATIONS
DILWYN FORMATION
PEMBER MUDSTONE
PEBBLE POINT
MASSACRE SHALE
PAARATTE FORMATION
BELFAST FORMATION
WAARRE C
WAARRE B
WAARRE A
EUMERELLA FORMATION
Source of carbon dioxide: Buttress-1 well

compressor

CRC-1 injection well

After cooler
Naylor-1 Site

Integrated
Bottom hole
Assembly

Naylor 1

2040 m Depth
80°C
17MPa (2500 psi)

Perf
2028 to
2032

Gas

Water

2050 m

2055 m

Total Depth: 2060 m

Integrated

Rod 0.75

Pressure/Temp and
U-tube Inlet

Geophone with clamp
(1.125 V x 1.5” 3C)

Hydrophone (1.25"

Perf
2039 to
2045

Geophone with clamp
(1.125 V x 1.5” 3C)
Atmospheric monitoring

- Monitoring began late 2006
- Existing CO$_2$ sources characterised
- No evidence of emissions from CO$_2$ storage to date
- Monitoring using CO$_2$ concentration alone needs ideal conditions, so other species including CH$_4$, SF$_6$, CO and $^{13}$CO$_2$ are monitored to enhance sensitivity
Atmospheric monitoring

- Select daytime baseline conditions
- Day 1 - normal day
- Day 2 - drill rig activity

3 ppm elevation

Cape Grim baseline

D. Etheridge
Soil gas monitoring

No large circles which could indicate a leak.

Summer 2008

$\delta^{13}C_{CO_2}$ (%)

-24.2 - -20.0
-19.9 - -15.3
-15.2 - -12.7
-12.6 - -10.0
-9.9 - 0.0

The measured $\delta^{13}C_{CO_2}$ values for Summer 2008 show a range from -24.2 to 0.0%. There are no large circles indicating a potential leak.
Hydrodynamics & groundwater Monitoring (Near-Surface)

**Objective:**
- Monitor water levels to determine seasonal variation, flow rate and direction
- Identify any chemical changes associated with possible CO2 leakage

**Methods:**
- Dataloggers
- Water chemistry

Aquifers monitored:
- Shallow unconfined Port Campbell Limestone,
- Deep confined Dilwyn aquifer
Downhole fluid sampling

- U-tube surface facility (yellow container) – above
- Isotube sample cylinder – left
- Inside the u-tube surface facility - right
Integrated Bottom hole Assembly

Naylor 1 Monitoring Well

2040 m Depth
80°C
17 MPa (2500psi)

2040 m Depth
80°C
17 MPa (2500psi)

Integrated monitoring assembly
- 3 geophones, 3 hydrophones and 2 P/T sensors below the packer
- 3 U-Tubes:
  - In the gas, below GWC, Water
- 3 three-component geophones above the packer
- An array of 8 single component geophones above these

Injection phase - prediction

**Arrival:**

4-8 months

**CRC-1**
Injection well

**Naylor-1**
Monitoring well

- Depth ~2000m
- 300m
- CO₂
- Methane
- U-Tube-1
- U-Tube-2
- U-Tube-3

Arrival: 4-8 months
Seismic monitoring

- Range of seismic techniques
- Vertical Seismic Profiling (VSP) (source surface, receiver downhole)
- High Resolution Travel time
- Microseismic surveys (measures creaks in the subsurface)
Repeatability issue

Weathering conditions: top soil (farming zone) + weathered clay-rich zone on top of karstic limestone

Seasonal variation of Water Table

Variable scattering with WT variation

TL seismic at same soil saturation – same time of the year
Time lapse 3D seismic: various sound sources used

Results look very promising
Conclusions from Stage 1

- Good quality TL 3D surface data were acquired
- Base line seismic data recorded with free fall WD source (concrete breaker) first monitor with MV; very good (post-stack) repeatability achieved!
- CO2- CH4 replacement detected with high-res, high fold-TL seismic!
- Changes in soil saturation produce kinematic effects (statics, stacking velocities) and produce different ground roll patterns
- CO2 upward migration readily detectable
- 3D repeatability much higher than 2D repeatability
- Low S/N low NRMS (strong source for pre-stack, high-fold for post-stack)
- M&V of CO2 storage in depleted gas fields could be achievable with 3D TL seismic despite initial grim predictions
- Jan 2010; Post injection TL (3D surface + 3D VSP), verify current TL result
What has CO2CRC Stage 1 achieved so far?

- Demonstrated safe and effective storage of 65000 tonnes of CO2 in a depleted gas field with no leaks
- Confident that would detect a small ‘leak’ into the overlying formation
- Confident that would detect a significant leak into the atmosphere and the soil
- The reservoir models gave good predictions of “break through”
- Have been able to sample ‘in situ’ formation waters from 2 km depth, but still resolving some sampling issues
- The seismic results appears to be giving an image which is very consistent with the reservoir model.
- The community has remained supportive and interested
- The regulators are happy
What do we hope to achieve during CO2CRC Otway Stage 2?
Storage capacity

\[ G_{CO_2} = A \times h \times \phi \times \rho \times E \]

- **Areal Extent**
- **Thickness**
- **Porosity**
- **Density**
- **Efficiency**

Diagram showing:
- Structural & stratigraphic trapping
- Residual CO₂ trapping
- Solubility trapping
- Mineral trapping

% Trapping contribution vs. Time since injection stops (years)

- Residually trapped CO₂
- Rock grains
- Water
- Flow of CO₂

CO₂ CRC
Schematic Stratigraphic Column of Otway Basin
CO2CRC Otway Project - Stage 2: Focus on Non-Structural Trapping Mechanisms

2A: Drill Well

2B: Residual Saturation Test

2C: Larger Volume Injection
Visualisation of the Parattee CO$_2$ overlying the Warree

OTWAY PROJECT STAGE 1 AND STAGE 2
Zones Identified in Paaratte Formation

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5
- Zone 6
- Zone 7
- Zone 8

Permeability (md)
Understanding at a Pore Level
Storage Capacity

\[ G_{CO_2} = A \times h \times \Phi \times S \times E_s \]

**Why the order-of-magnitude variability?**

- Free-phase versus dissolution
- Entire aquifer versus traps only
- Efficiency factors
CO2CRC Otway Enablers are in Place
Stage 2: Scientific objectives

• Investigate whether seismic borehole and/or surface methods can be used to monitor huff-and-puff dynamics in a saline aquifer (Paaratte).

• Verify numerical simulations/predictions by the field measurements.

• Compare the effectiveness of 2D vs. 3D time-lapse measurements for monitoring.

• Establish distribution of CO2 within a reservoir from remote measurements.

• Use time-lapse seismic anisotropy to verify pore-pressure changes, fluid migration, and saturation.

• Develop multi-level injection monitoring system.
CO2CRC/CSLF Otway Project
Leading edge collaborative international research
Thank you