CO2CRC Storage and Capture Demonstration

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Capture Manager

CO2CRC
BUILDING A LOW EMISSIONS FUTURE

CMTC
19 July 2017

Who is CO2CRC?

- CO2CRC is a world leading carbon capture & storage (CCS) research organisation that works closely with global industry to reduce large scale greenhouse gas emissions through:
  - Investigating carbon capture, transport and storage technologies
  - Examining the costs and drivers across the CCUS chain
  - Conducting research, development and demonstration across the CCUS value chain
  - Providing efficient collaboration amongst 150 researchers in capture and storage
  - Building experience in CCUS technology by addressing knowledge gaps

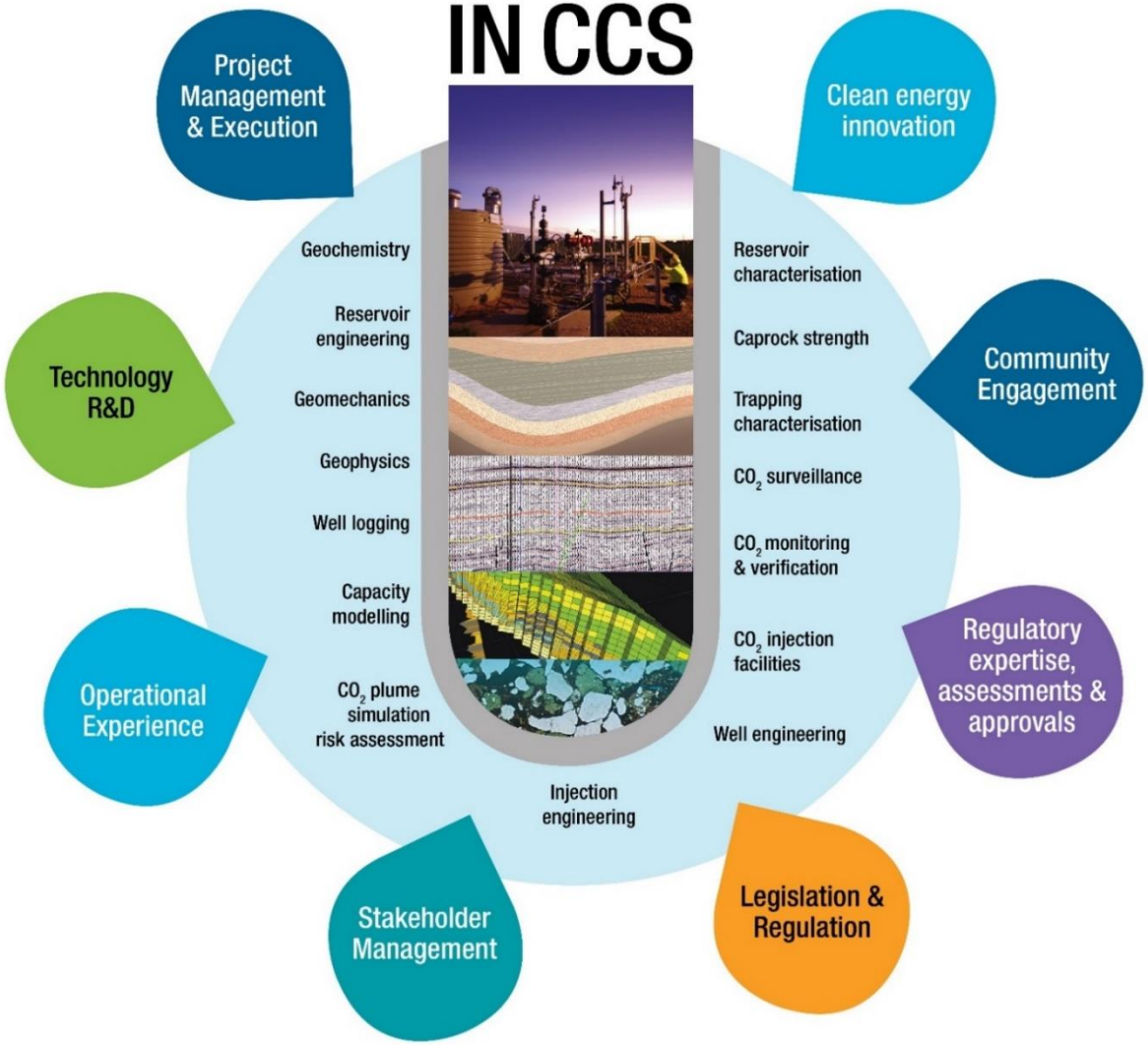
32 research and industry partners globally

WHO IS CO2CRC

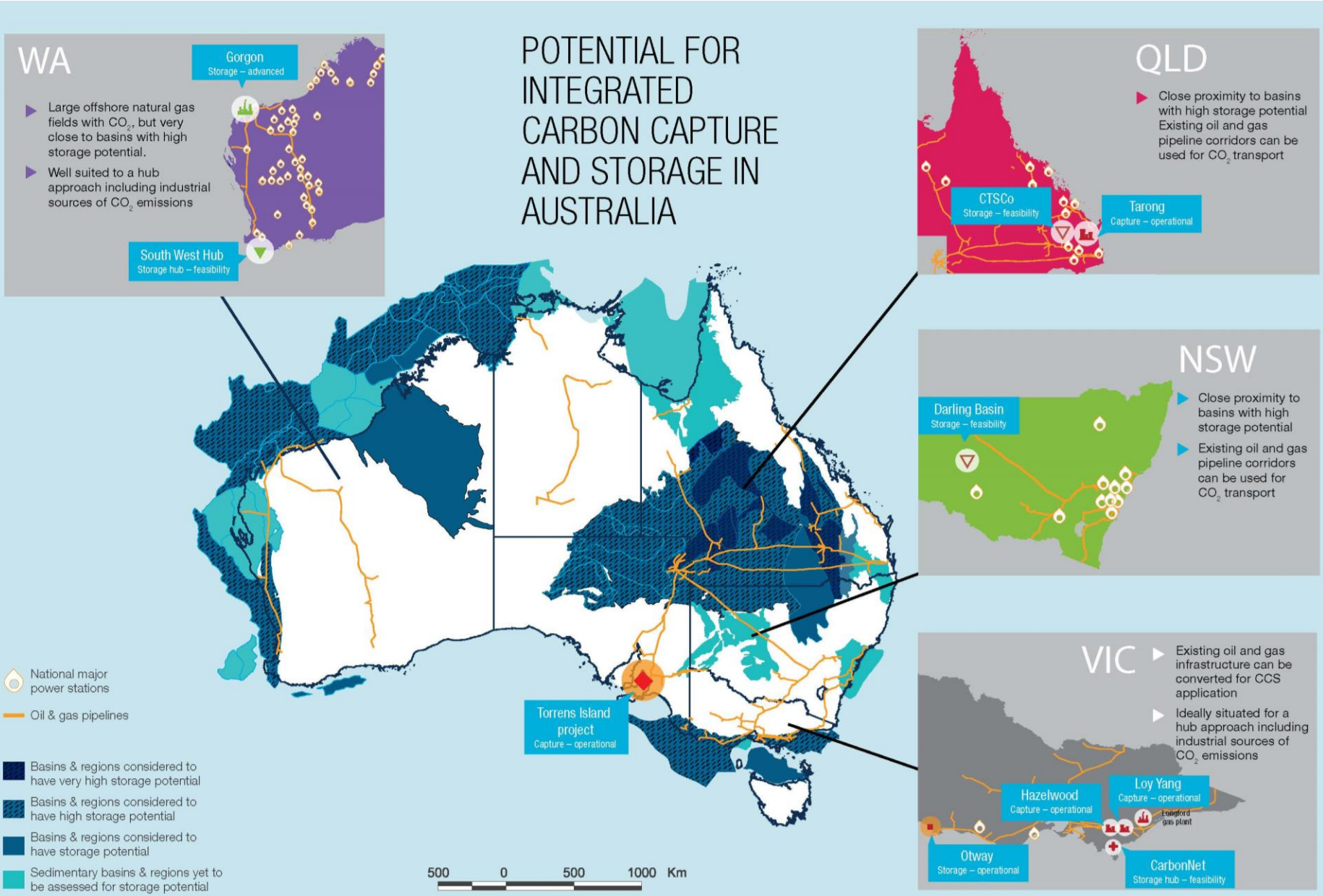
CO2CRC SUPPORTS INDUSTRY TO REDUCE GREENHOUSE GAS EMISSIONS THROUGH CARBON CAPTURE & STORAGE RESEARCH

- We are the first company in Australia to have undertaken carbon capture and storage end to end
- Our research demonstrates carbon capture and storage in-field using novel technologies. We test their efficiency, accuracy and cost-effectiveness bringing confidence to industry and regulators
- We have safely injected, monitored and contained 80,000 tonnes of carbon dioxide for more than a decade
- We design, project manage and fund carbon capture and storage programs utilising the best international and local talent

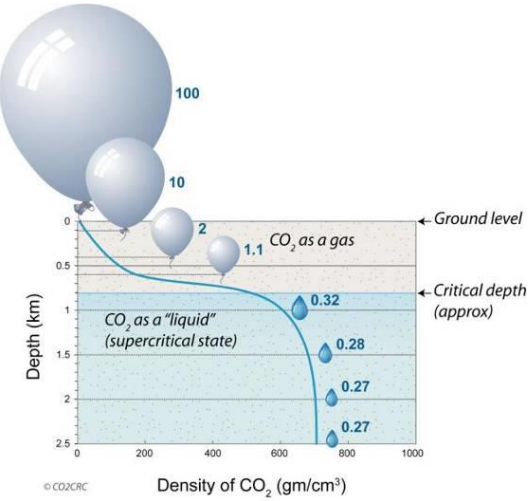
CO2CRC END TO END EXPERTISE IN CCS

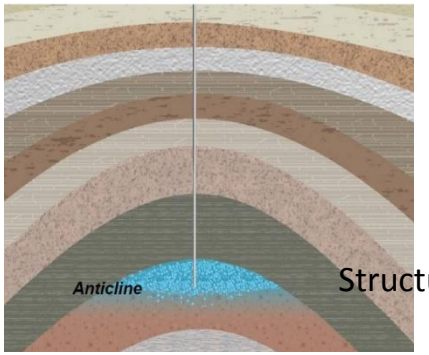


Australia's Integrated CCS activities

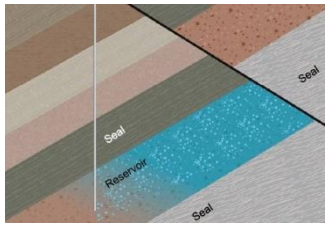


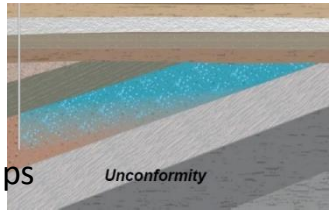
How is Carbon Dioxide Stored Geologically?

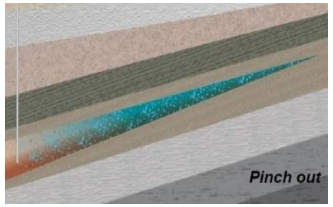


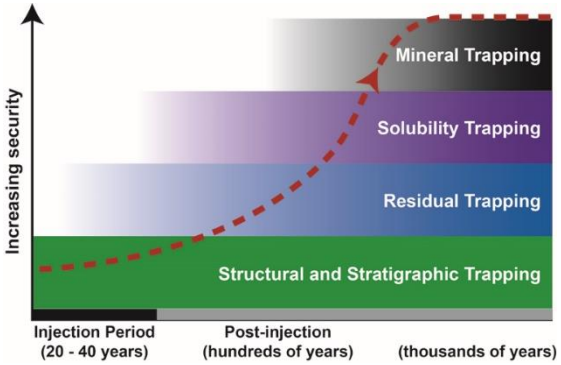


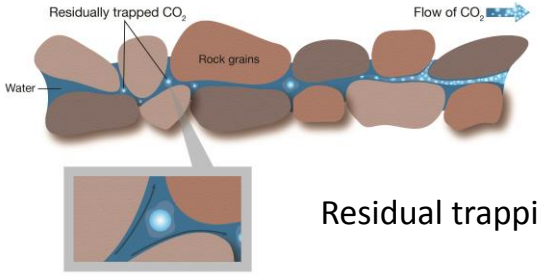
Structural traps











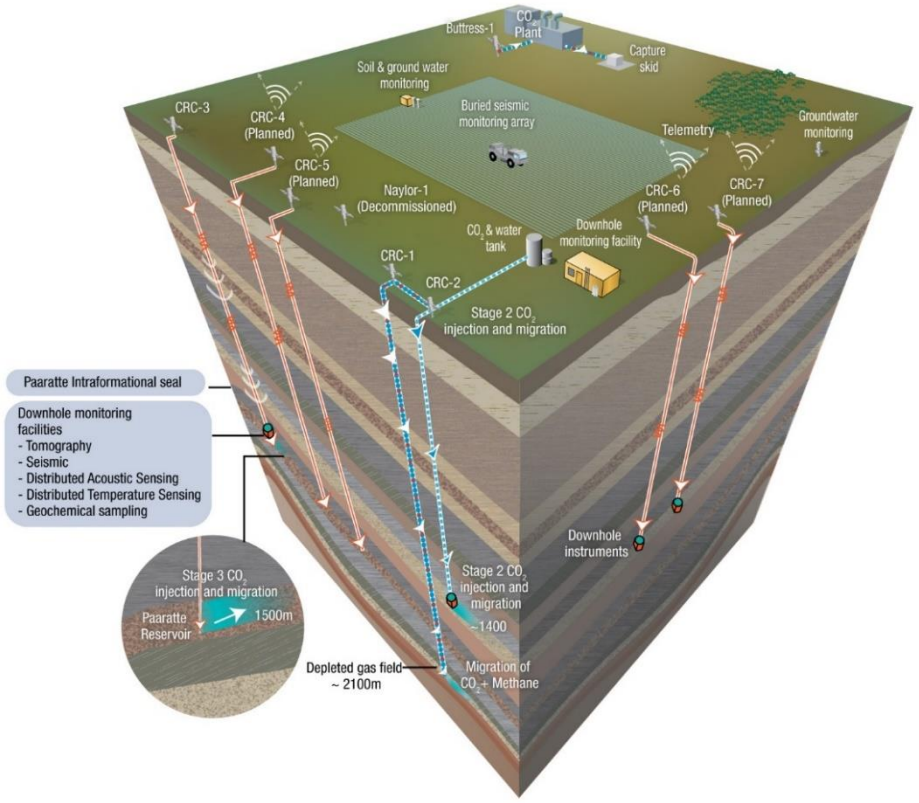
Residual trapping

Otway Site from above

Proposed new well locations

CO2CRC Otway Storage Projects

- Stage 1: 2004 – 2009 (Concept)
  - ✓ Demonstrated safe transport, injection and storage of CO_2 into a depleted gas reservoir
- Stage 2: 2009 – 2019 (Risk Reduction)
  - ✓ Demonstrate safe injection and monitoring into a saline formation
- Stage 3: 2016 – 2028 (Cost Effective Storage Management and Subsurface Monitoring)
  - ✓ Demonstrate safe, reliable and cost-effective subsurface monitoring of CO_2



Otway Stage 2

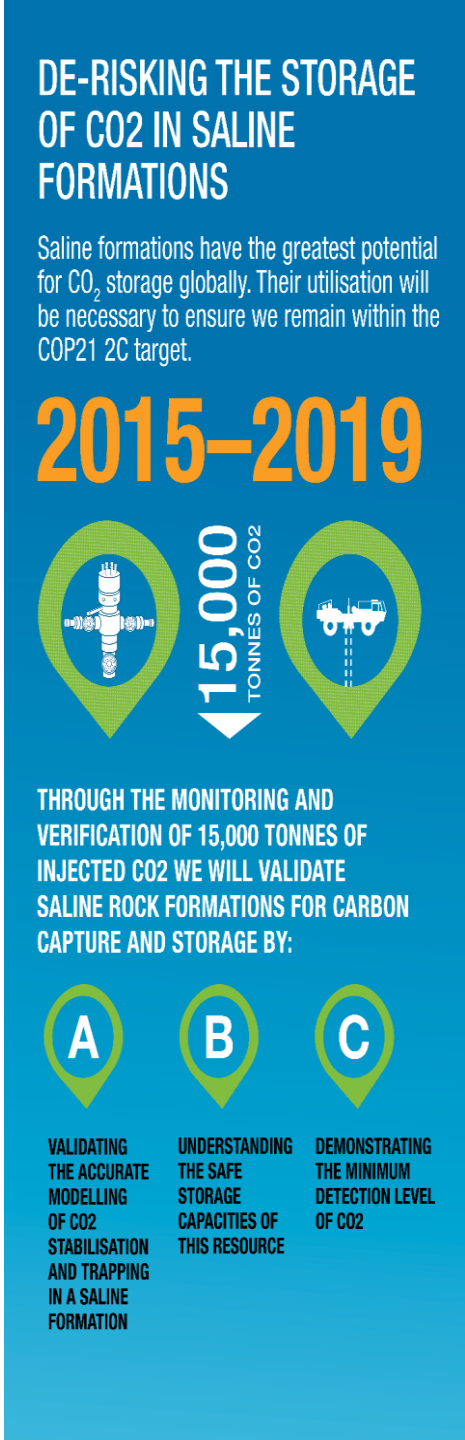
Demonstrate that CO_2 storage can be safely conducted at scale within a Saline Formation

Appraisal

- ✓ 2A :Drill CRC-2
- ✓ 2B: Measure parameters affecting residual and dissolution trapping in a saline formation
- ✓ 2B Extension: interactions with impurities & well test refinement

Operation

- 2C: Spatially track injected CO_2 in a saline formation
  - ✓ Minimum detection limit
  - ✓ Migration behaviour
  - Stabilisation (on track for 2018)



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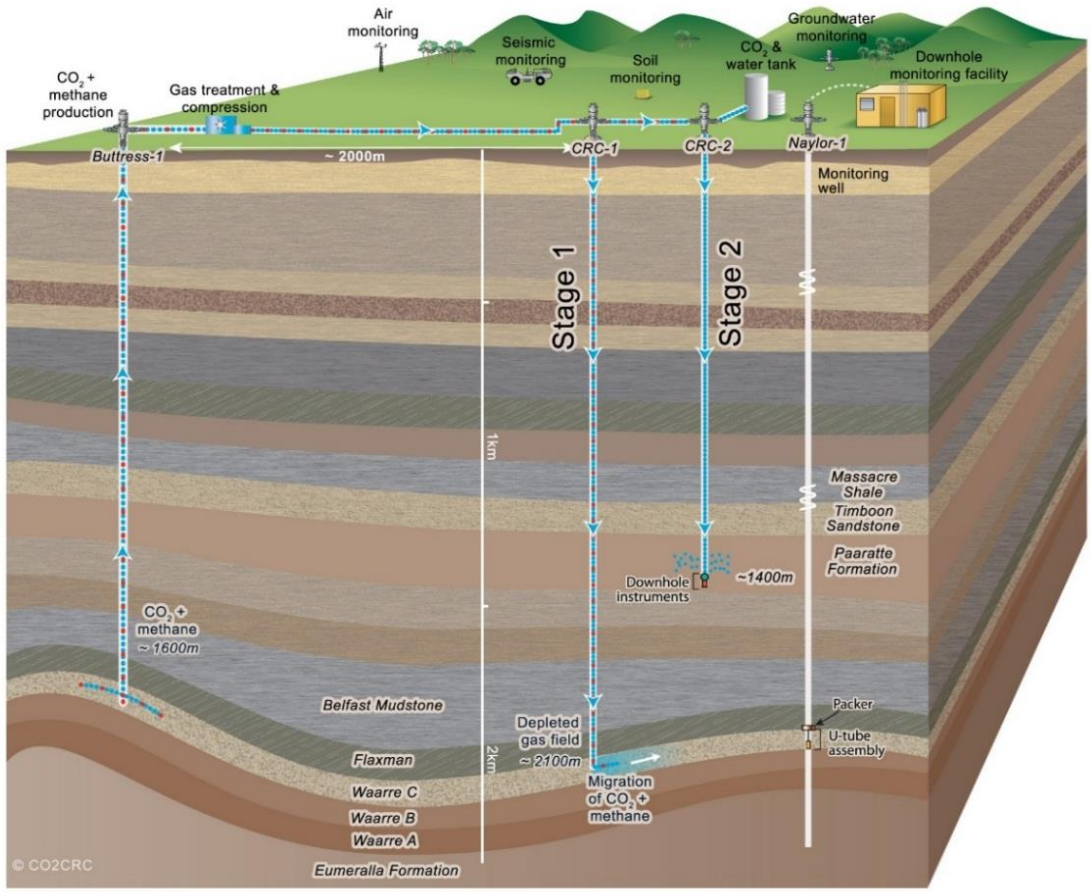
Otway Stage 2B – Conclusions

- Residual trapping is a key mechanism for the storage of carbon dioxide in saline formations
- The test measures field-scale residual trapping using a single well configuration and six different methods – pressure, temperature, pulsed neutron logging, noble gas tracers, reactive tracers and a dissolution test.
- The field results enable us to evaluate the effectiveness of each method, and to recommend how such a test could be improved.

CO2CRC Otway Storage Project Stage 2C



DE-RISKING THE STORAGE OF CO2 IN SALINE FORMATIONS

Saline formations have the greatest potential for CO_2 storage globally. Their utilisation will be necessary to ensure we remain within the COP21 2C target.

2015–2019

15,000 TONNES OF CO2

THROUGH THE MONITORING AND VERIFICATION OF 15,000 TONNES OF INJECTED CO2 WE WILL VALIDATE SALINE ROCK FORMATIONS FOR CARBON CAPTURE AND STORAGE BY:

A VALIDATING THE ACCURATE MODELLING OF CO2 STABILISATION AND TRAPPING IN A SALINE FORMATION

B UNDERSTANDING THE SAFE STORAGE CAPACITIES OF THIS RESOURCE

C DEMONSTRATING THE MINIMUM DETECTION LEVEL OF CO2

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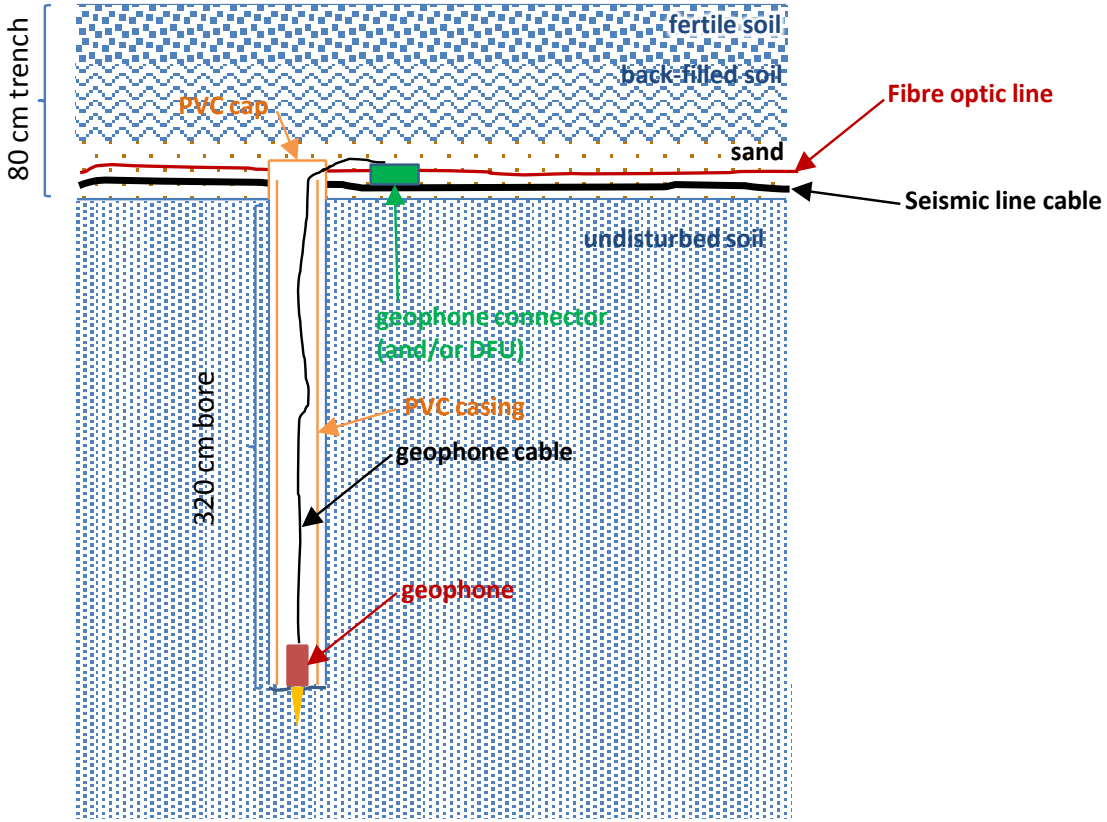
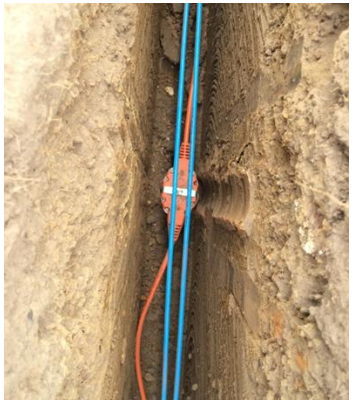
Seismic Array

- *Installation of 1km seismic array.*
- *900 monitoring devices – geophones*
- *Over 30km of fibre optic cable*
- *Receivers buried 4 metres underground*
- *Lines 100 metres apart, receivers 15 metres apart*
- *Installed in early 2015*



Geophone and fiber array installation

Geophones

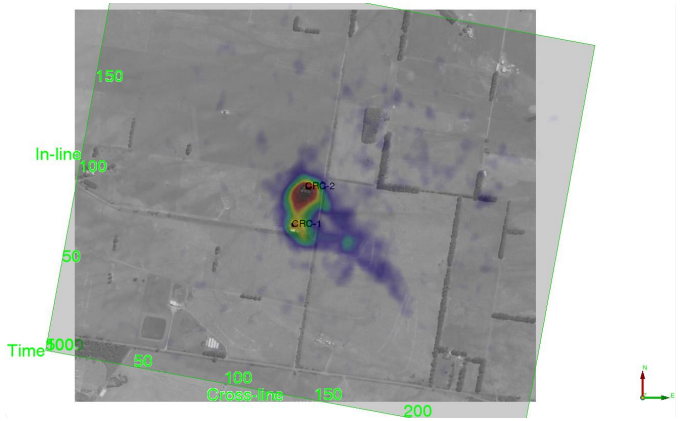


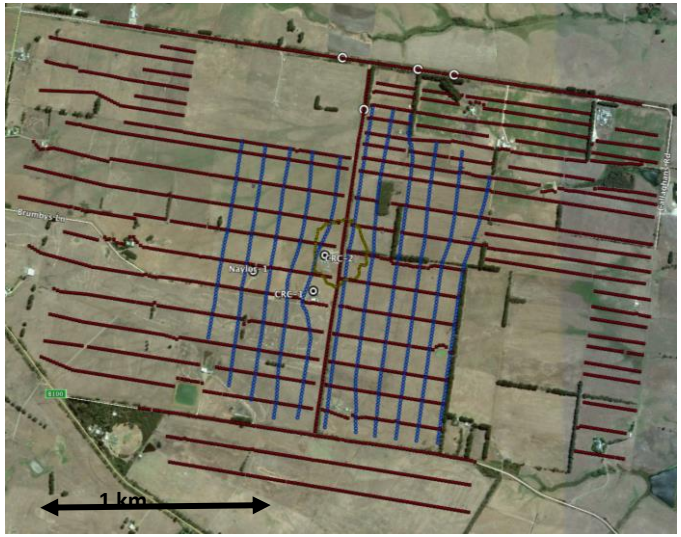
Deployed in trench

Fibre optic cable

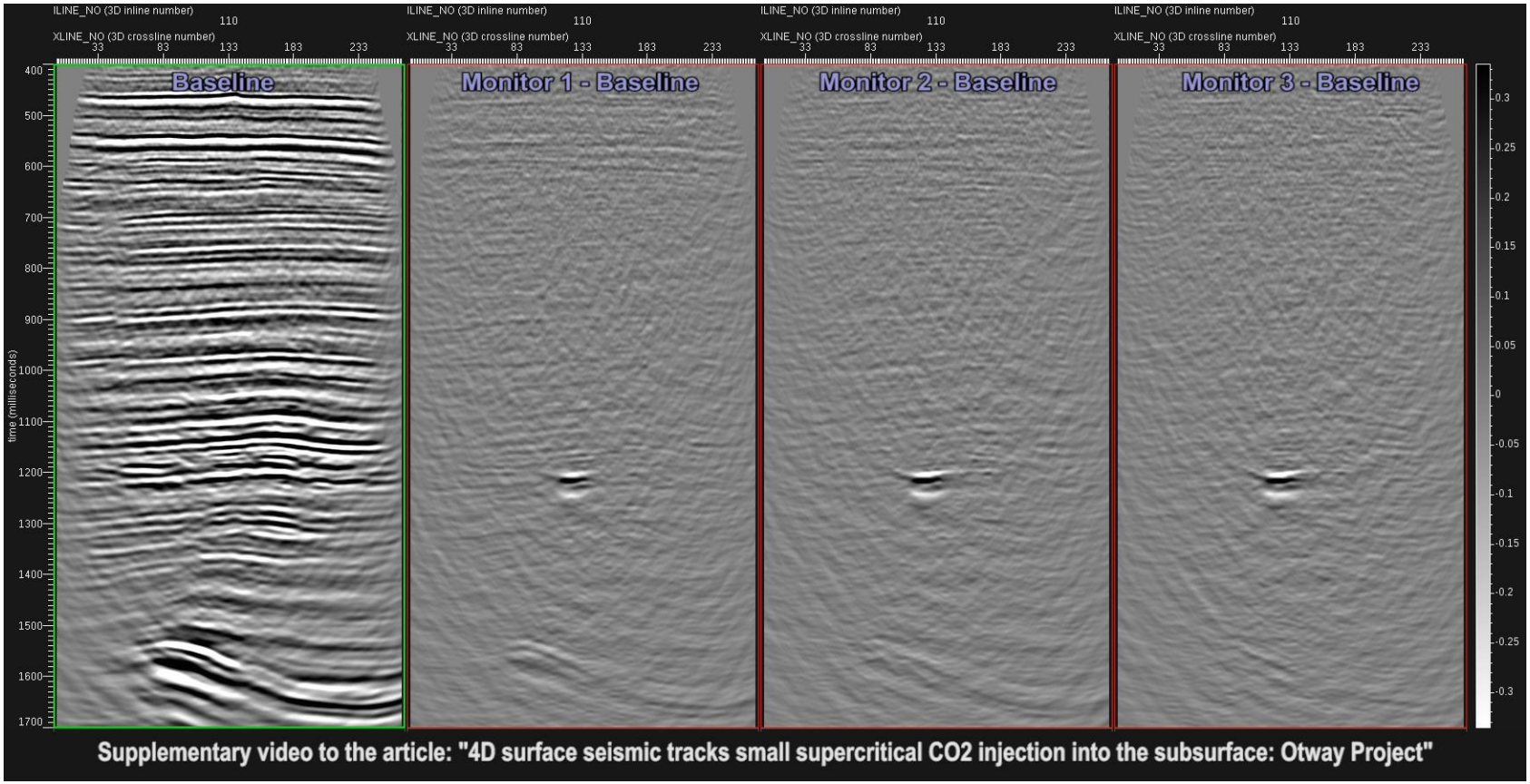
Otway Stage 2C Preliminary results

1. *15,000 tonnes of CO_2 safely injected into a saline formation, migrating as predicted*
2. *Seismic and pressure monitoring resolution is beyond expectations*
3. *Minimum detection levels of supercritical CO_2 are being evaluated through the direct observation*
4. *The combination of these results, with ongoing regular monitoring through to 2019, will de-risk the injection, monitoring and trapping of CO2 in a saline formation giving confidence to technology users and regulators.*

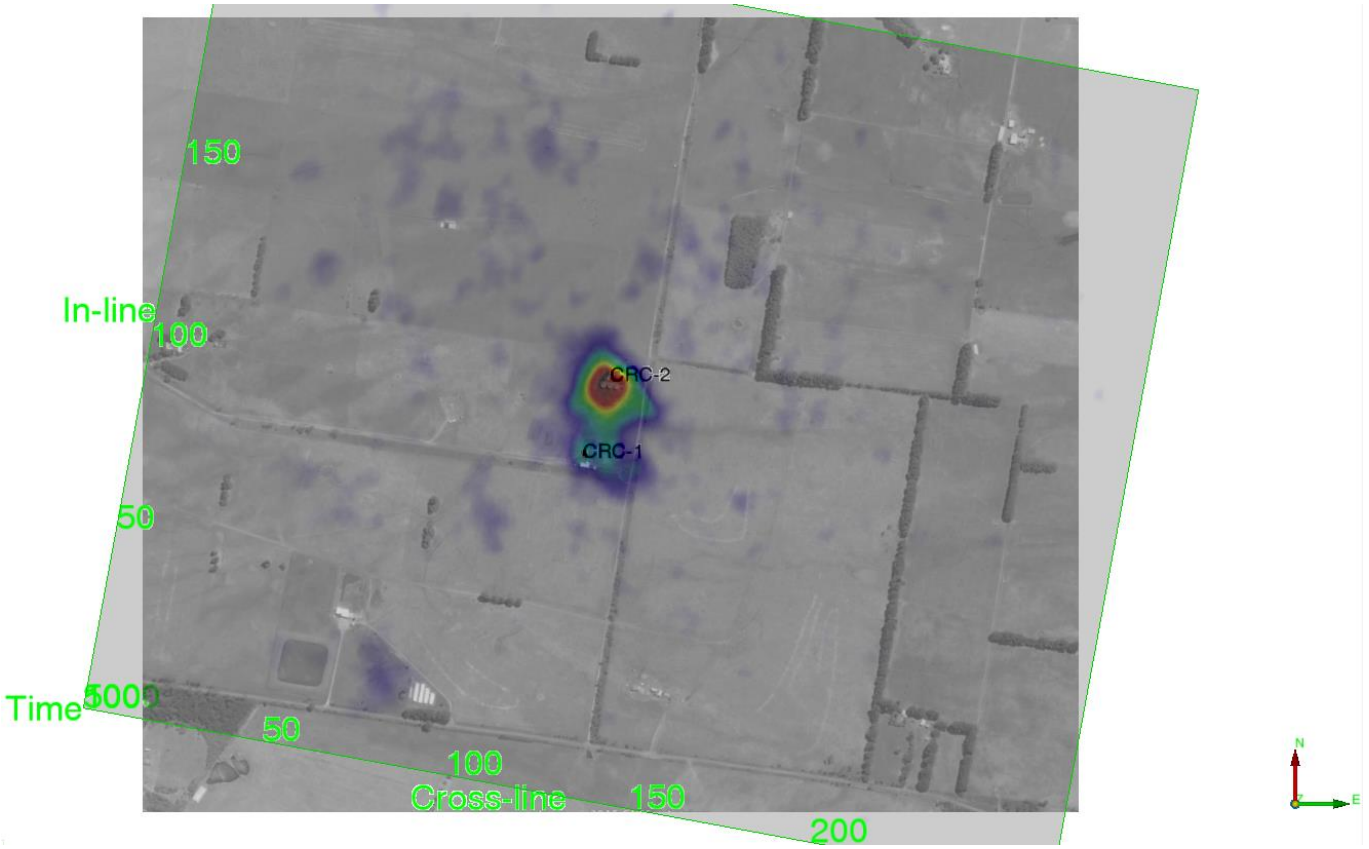




Otway Stage 2 – 4D change still image



Energy(M1 – B)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CRC-2
CRC-1
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Cross-line
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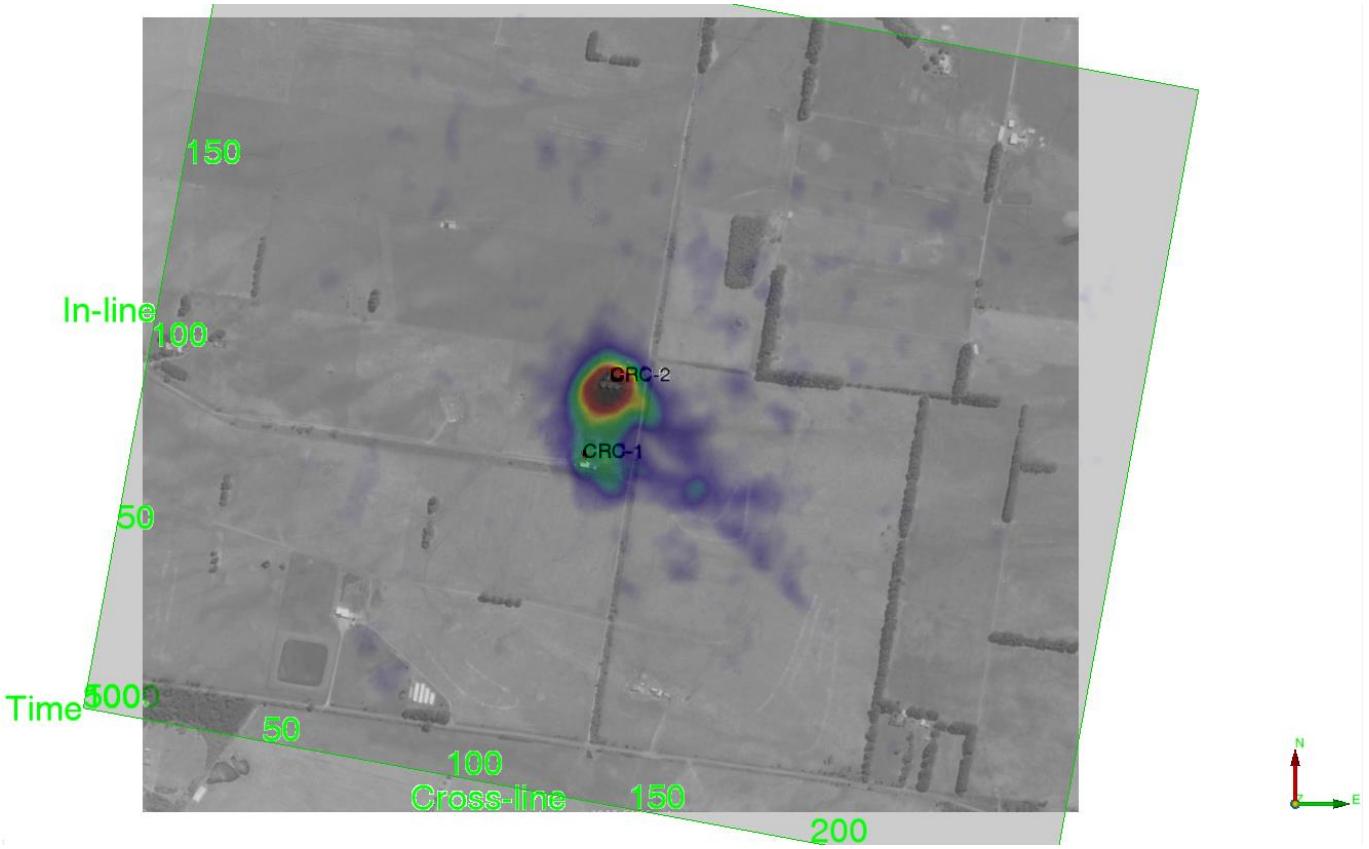
Energy(M2 – B)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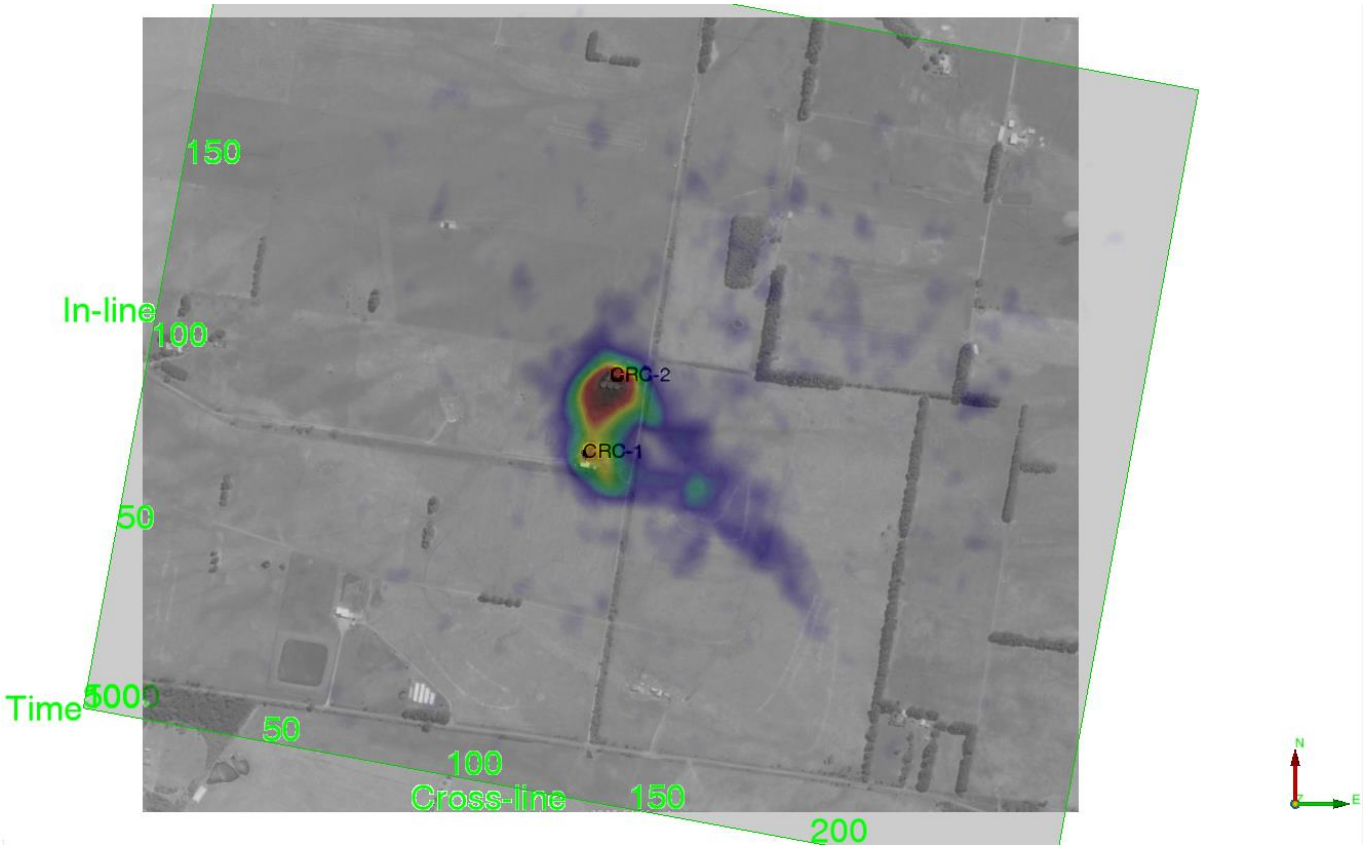
Energy(M3 – B)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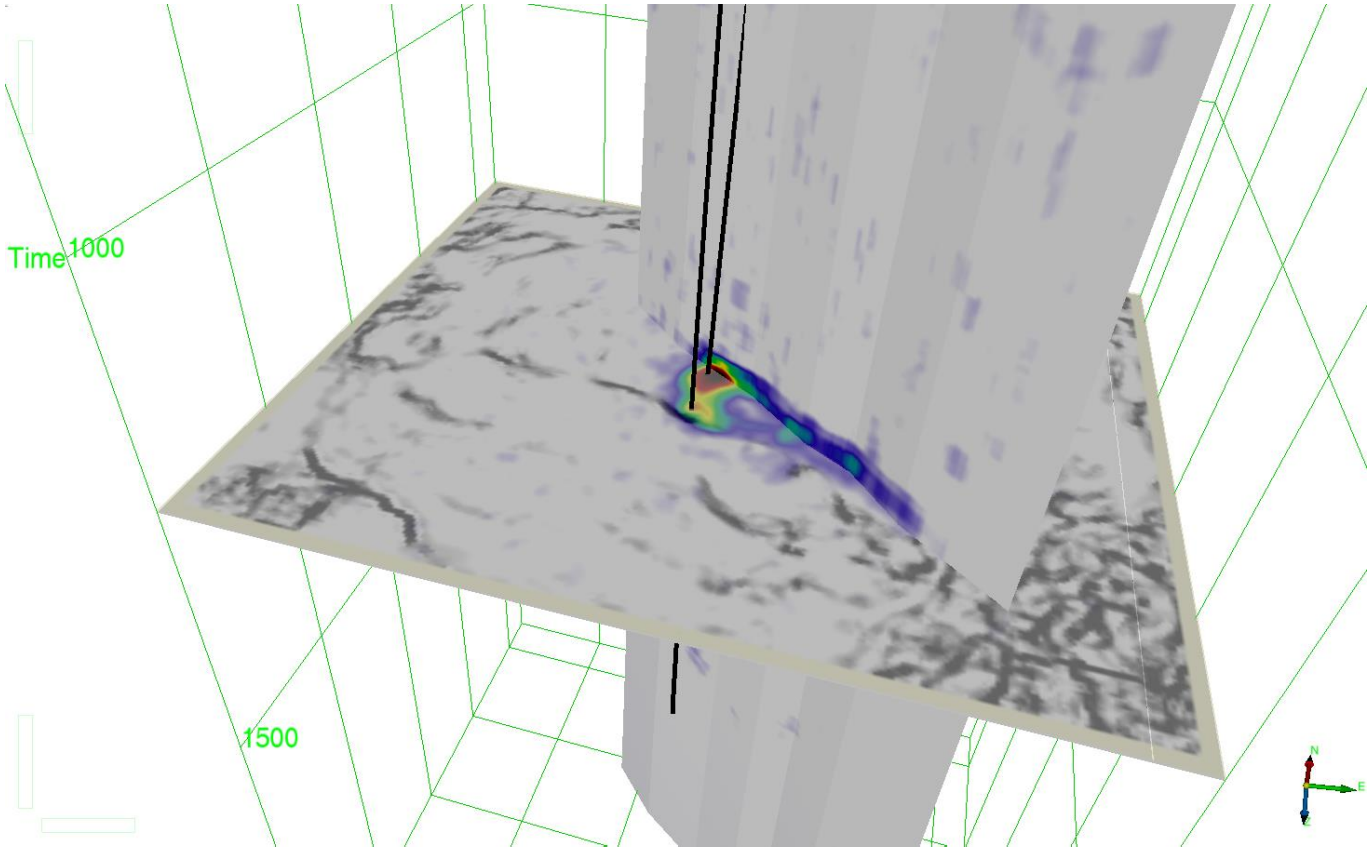
Otway Storage Project Stage 2C



Highlights on Storage

Exceptional Datasets

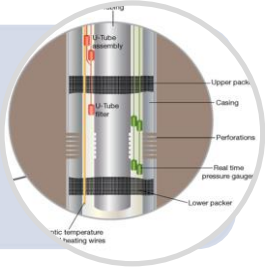
- Atmospheric (continuous monitoring)
- Soil Gas
- Seismic
- Reservoir fluids

Field Validation

- Validation of models in actual field tests
- Fully permitted and operational site
- Availability of CO_2
- Globally unique advantage

Developing Novel & Innovative Concepts & Technology

- Single Well Test for reservoir characterisation
- Several generations of U-Tube systems deployed
- Fibre Optics for reservoir interrogation and well diagnostics
- Innovative well instrumentation



First of its kind experiments

- First CO_2 storage demonstration project in Australia
- Reducing risk and uncertainty
- Advising regulators and project proponents in Australia and world wide
- A go-to project

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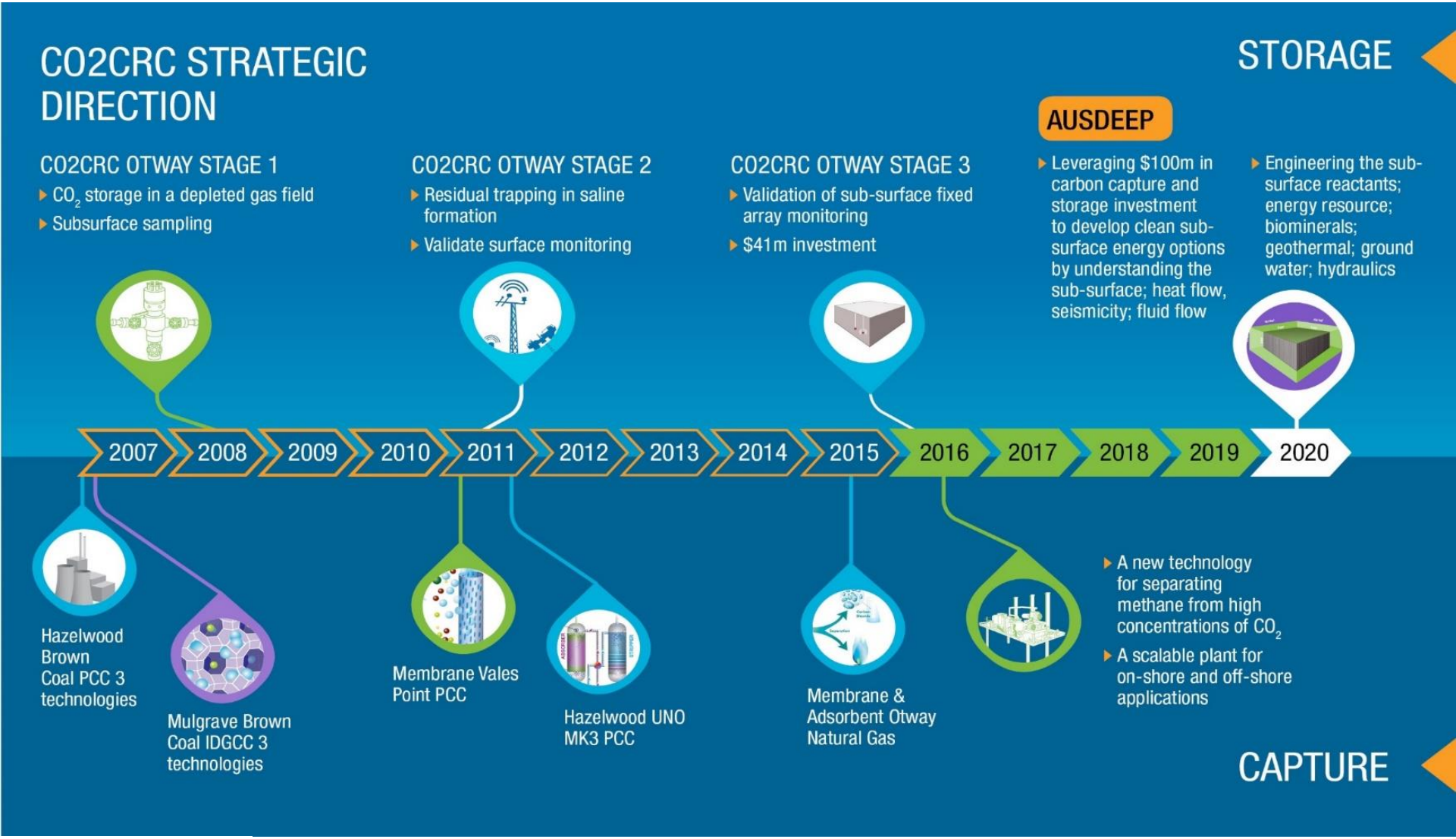
Success Factors for the CO2CRC Otway Project

1. A locally based Site operator who is available all year round at short notice.
2. A locally based Community Liaison Officer who is contactable always.
3. The availability of gas on call from Buttress-1 at no further cost.
4. The proximity and availability of pure CO_2 gas from Boggy Creek at market cost.
5. Supportive land owner community.
6. Availability of formations and structures in the sub surface that allow safe injection of product.
7. A surface facility that has been built (right standard and superior materials) to last a long time.
8. A workable regulatory setup for R&D type work. Approvals to inject both CO_2 and Buttress-1 gas and produce formation water.
9. Project expertise availability as and when required.
10. Monitoring
11. Demonstrating it can be done under Australian conditions

We have the social licence to operate

What does our future activities look like?



Implications of results to date

- *CO2CRC is delivering a broadly applicable procedure to predict, monitor, verify & assure CO_2 migration & trapping in saline formations*
- *Otway 2C is providing in-field evidence for the use of saline formations as a suitable CO_2 storage targets*
  - Validation of CO_2 behaviour is achievable, and
  - CO_2 behaviour in saline formations is predictable
- *The project outcomes provide a clear foundation to future operators and regulators to the leakage assurance threshold in the subsurface*
  - The minimum technical limit for a surface-based risk-targeted seismic monitoring system has been determined

REDUCING THE COST OF CO2 STORAGE

CO2CRC aims to accelerate the implementation of commercial carbon capture and storage projects by undertaking the validation of cost-effective subsurface monitoring technologies

2016–2022

BY 2022 WE WILL FULFIL THE FOLLOWING OBJECTIVES:

A — DELIVERY OF PERMANENTLY DEPLOYED, COST- EFFECTIVE REAL-TIME MONITORING SOLUTIONS

B — INCREASE CO2 STORAGE MONITORING EFFICIENCY WITH NEW TECHNOLOGIES

C — REDUCE THE SURFACE FOOTPRINT AND IMPACT OF MONITORING ACTIVITIES

Stage 3 CO_2 Storage Management & Subsurface M&V $49.5 million project

1. We will develop a high-resolution, **real-time monitoring** capability. The technologies will provide an early warning solution for industry and regulators.

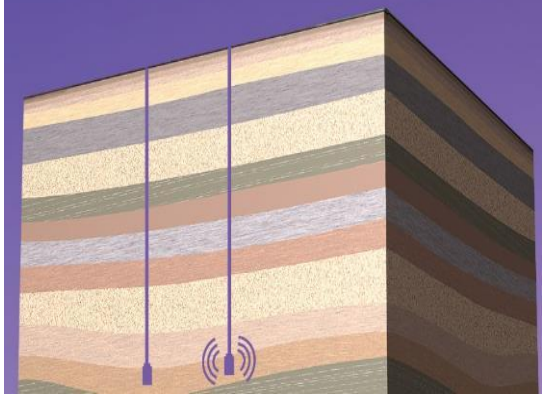
2. We will provide non invasive monitoring techniques that will be acceptable for community and regulators.

3. The project will provide a prospectus of technologies and workflows that can be used to define costs in commercial monitoring projects.

4. The project will evolve technology from benchtop application to in-field validation, which is being driven by current and prospective operator need.

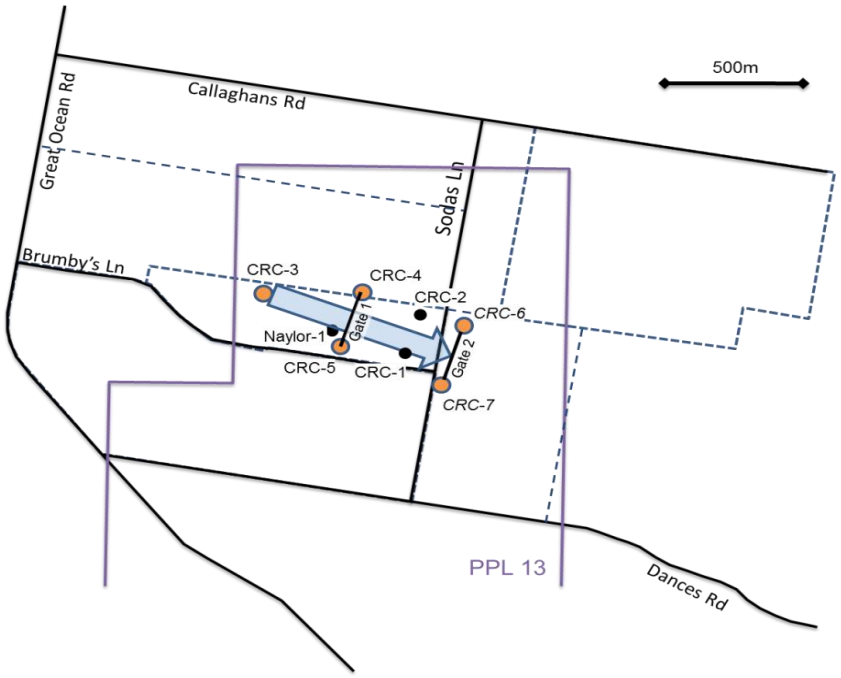
DELIVERING OUTCOMES

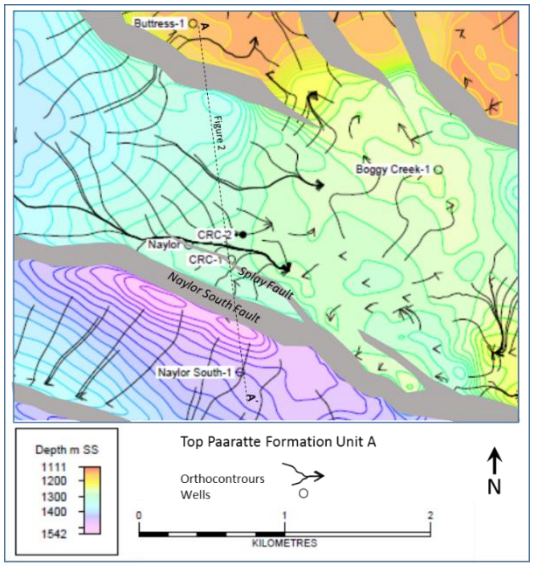
- Determine, and demonstrate the most cost-effective subsurface monitoring solutions, saving industry hundreds of millions of dollars in monitoring over the life of a project
- Inject 40,000 tonnes of CO_2 to generate a plume analogous to a leakage event of 1% of a commercial scale project

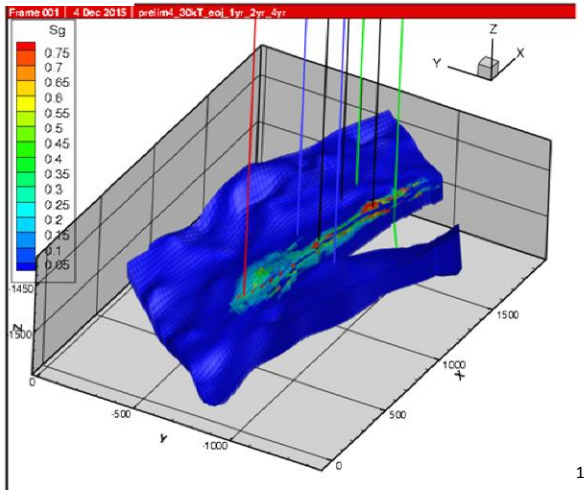


Otway site specific

Otway Storage Project
Stage 3 Concept

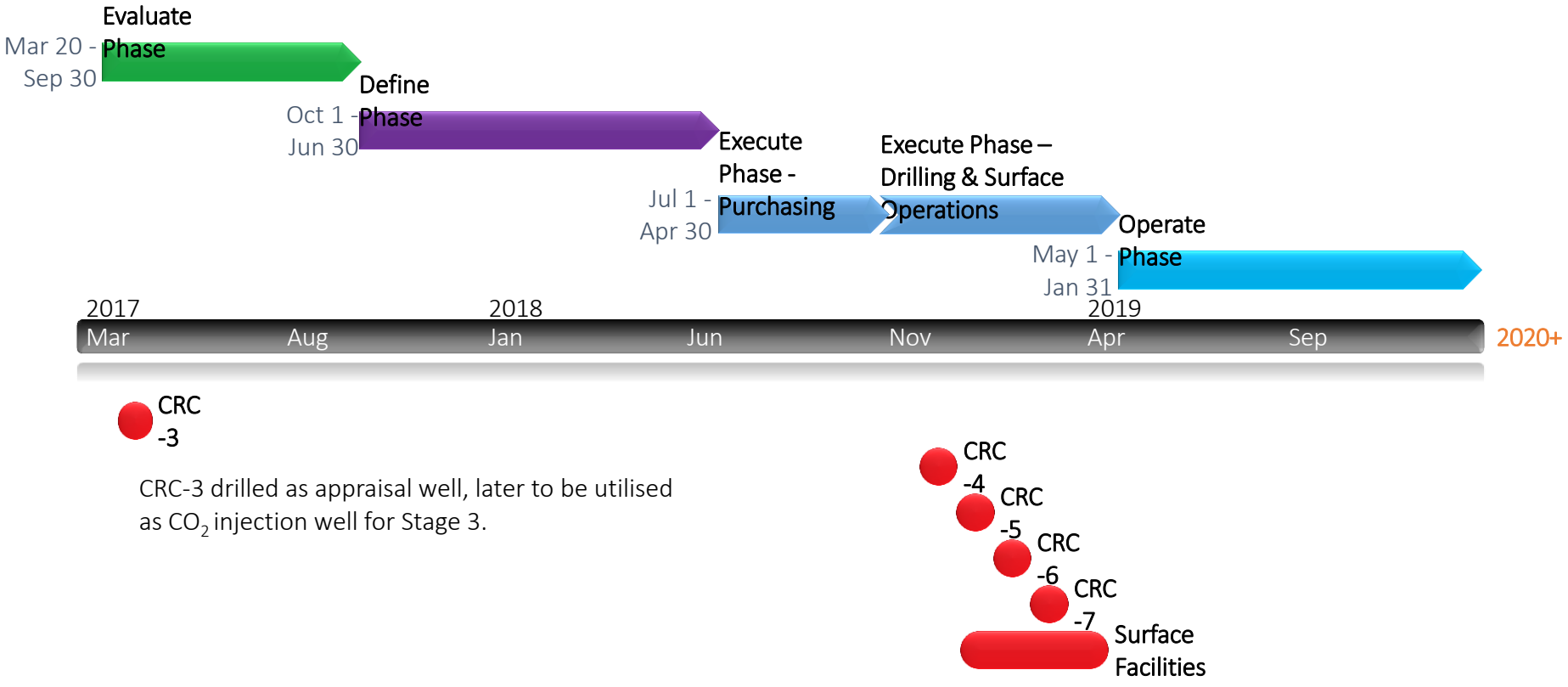






Otway Stage 3 Project

Project Timeline



CRC-3 drilled as appraisal well, later to be utilised as CO_2 injection well for Stage 3.

Field Capture Projects

- First application of 3 different capture technologies in parallel and their comparison for large scale implementation
- Attained capability of scaling up of capture plants from concept till large scale (TRL level 1 till 9) with economic feasibility

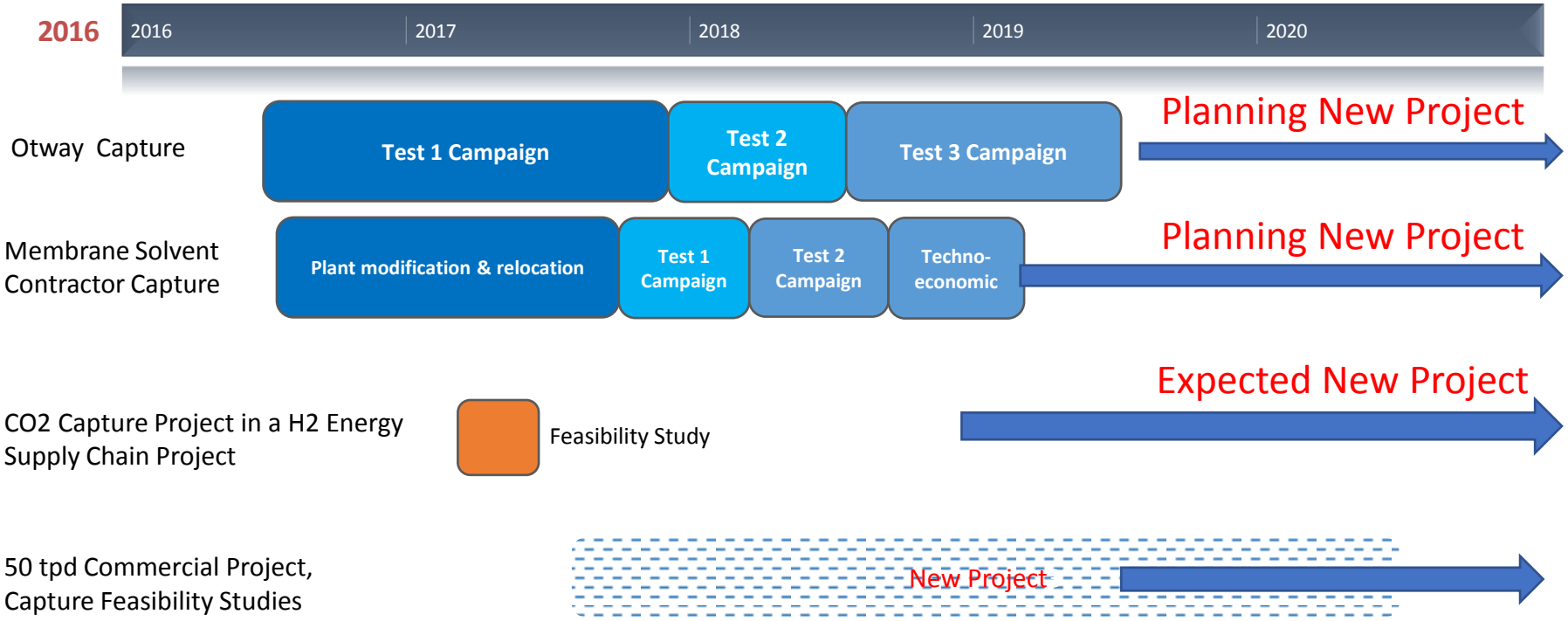
3 pre-combustion technologies at HRL, VIC :
2007-2011, ETIS/BCIA funded

3 post-combustion technologies at Hazelwood, VIC : 2007-2011 ETIS/BCIA funded

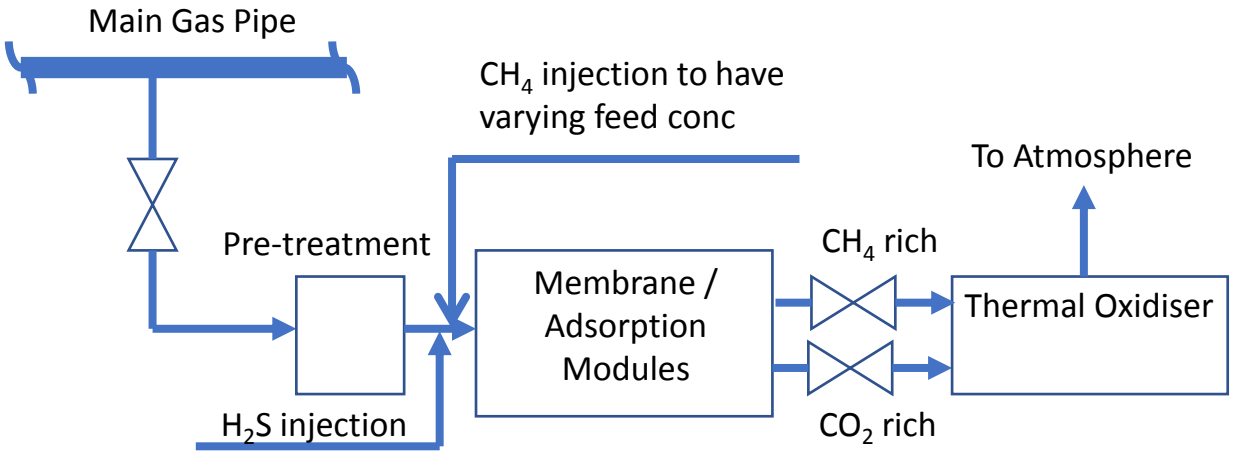
BCIA funded UNO MK 3 post-combustion at Hazelwood, VIC : 2011-2014

Membrane plant at Delta's Vales Point, NSW :
ANLEC R&D funded

Current and Future Capture Program Overview



Otway Capture Project



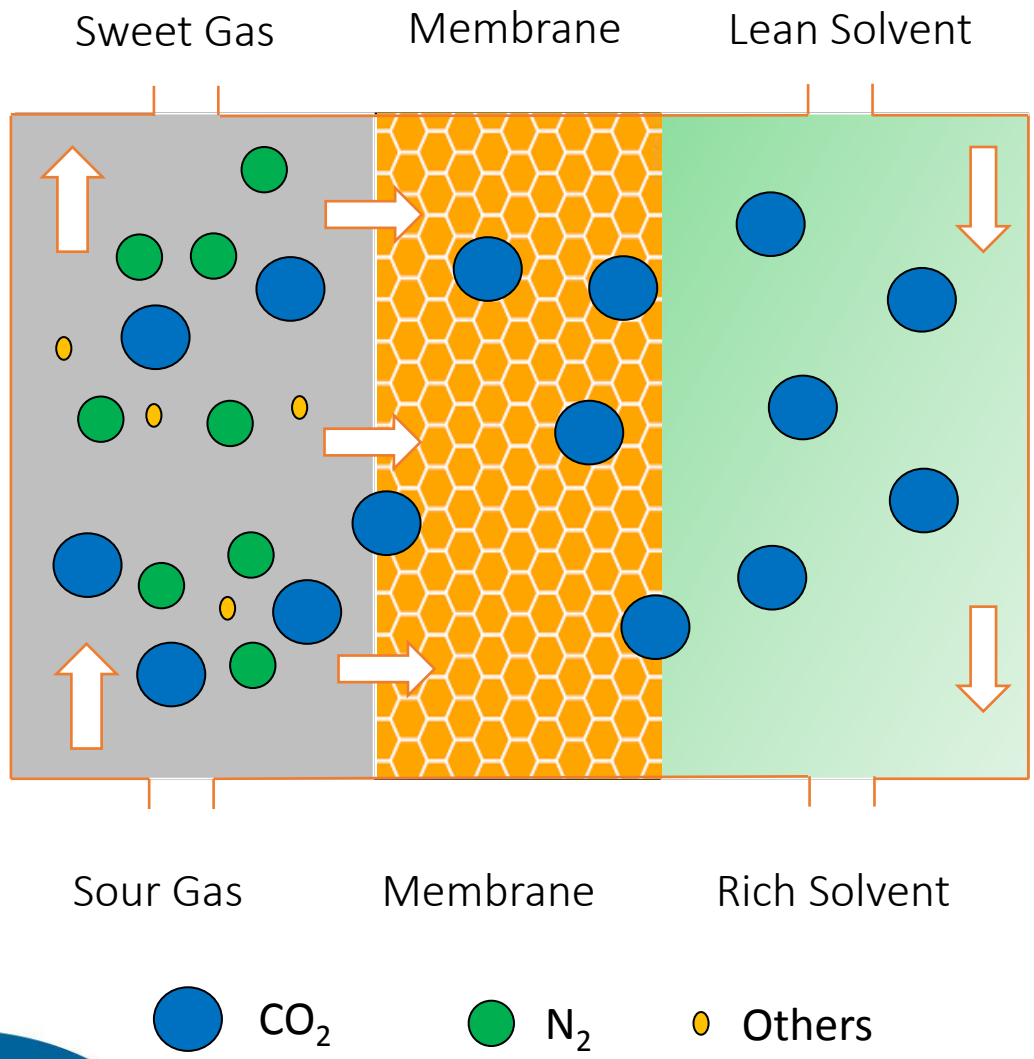
Project Aims

- To develop cost effective, compact technologies to capture CO_2 mainly from high CO_2 content wells.
- To test new capture materials (membranes and adsorbents) and develop new capture processes over a range of adjusted CO_2 concentrations

Main Features

- Feed Pressure: 80 to 30 bar
- Feed CO_2 Concentration: 5% to 80% achieved by CH_4 addition (existing is ~80% CH_4 and 19% CO_2)
- H_2S addition for impurities effect tests
- Rig on a common skid delivered on site for installation and commissioning (flow diagram shown left) 2016
- Adsorbent – 4 kg, Current use: Silica (S1), Second stage: Z1; Membranes – 3 different modules
- Opportunities for vendors to conduct long term testing of capture technologies for CO2/CH4 separation at a fully instrumented site

Membrane Gas-Liquid Contactors



- Avoidance of hydrodynamic issues.
- Equipment size reduced by 60 – 75%.
- Corrosion is significantly reduced.
- Around 40% reduction in operating costs.
- Around 35 – 40% savings in capital costs.
- Footprint requirements reduced by 40%.

Government, Industry and Research Partners

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Otway Site Operations

Appraisal (CRC 3) Well Operations

✓Rig operations lasted 30 days

✓Well was drilled to 1,667m depth

✓Executed FE Plan and gathered high quality dataset

✓Captured detailed lessons learnt

✓Maintained social licence to operate

✓Provided a pathway forward for Stage 3

✓ Achieved success in challenging wellbore operations

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CRC-3 Appraisal Well

Recovered Formation Evaluation Dataset

Wellsite Formation Evaluation Program				Post well Evaluation	
Wireline Logging	Coring	Well Injection Tests	Seismic Surveys	Drilling & Wireline Data	Core Analysis
Open Hole Logs ▪Survey, GR, Res, Sonic, Neu, Den, FMI, ECS, CMR ▪Cased Hole Logs ▪CBL (Full bore) ▪Completion Mapper	Targeting Primary Seal Primary & Secondary Storage intervals Recovered 127m , 3" core, 97% recovery	Injection Operations PS2: 100T injection PS1: 100T injection Data Recovered D/H Pressure in DST string D/H Pressure in CRC-2 Surface Pressures	DAS during cementing Zero Offset & Walk Away VSP Recording iDAS and Geophone data for comparison	Petrophysical Wireline Analysis Image Processing Wellbore Integrity Drilling Data EOWR M&V Well Design	Core Analysis Routine Special Digital MICP Palanology Hylogging