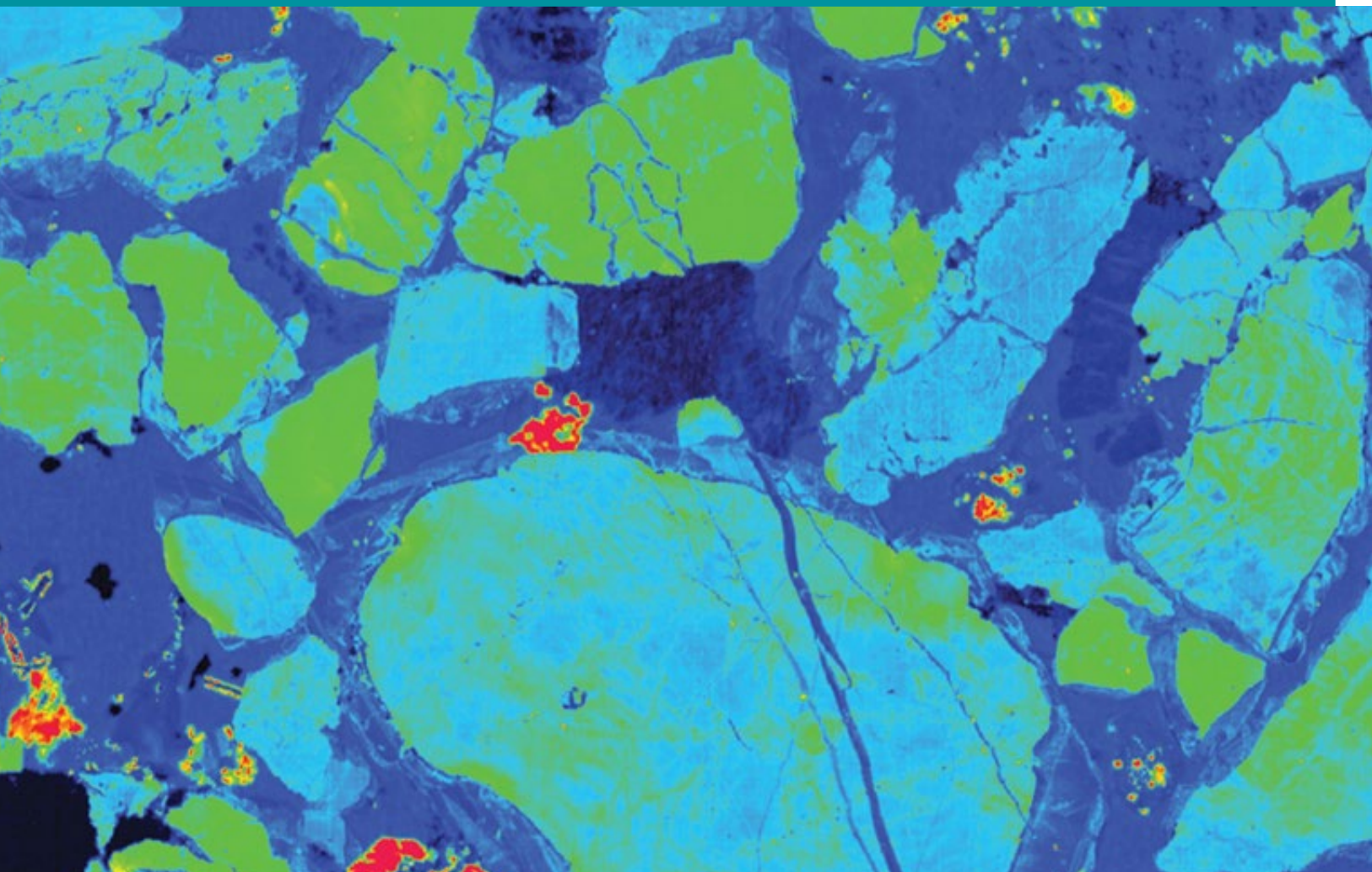


# National Geosequestration Laboratory



Delivering innovative research solutions to support Australia's carbon storage, energy and resources industries



# CONTENTS

- 1 FOREWORD
- 3 CARBON CAPTURE AND STORAGE
- 4 HISTORY OF THE NGL
- 6 IMPLEMENTATION
- 7 COMPLETED PROJECTS
- 9 RESEARCH PRIORITIES
- 10 RESEARCH CAPABILITIES
- 12 CASE STUDIES
- 18 DOING BUSINESS WITH THE NGL



# FOREWORD

Australia's energy sector underpins our economy and high standard of living. Technology and expertise to store carbon dioxide safely at a competitive price will be important to secure the benefits of this vital sector well into the future. It will play a role in our domestic energy sector with its high share of coal and gas fired power stations. It will also be important for the customers of our significant energy exports in the form of coal and liquefied natural gas (LNG). Geological storage is a key method to remove large amounts of carbon dioxide that would otherwise vent to the atmosphere.

The Australian Government is already taking significant direct action to reduce greenhouse gas emissions and supporting the commercial availability of low emission technologies. One of the Government's investment priorities is to ensure Australia has the capacity to permanently store carbon dioxide where necessary.

The National Geosequestration Laboratory (NGL) with

\$48.4 million of Australian Government funding through the Education portfolio is a very significant achievement in the creation of a world-leading infrastructure investment. The NGL provides critical research capability that can be deployed nationally and internationally to help reduce the risks and costs of subsurface carbon dioxide storage. To achieve this outcome, the NGL will work collaboratively with industry and deliver impact through internationally recognised research projects and engagement.

The NGL will also deliver education and training programs that will help build the next generation of scientists and engineers who will lead Australia's geological storage industry into the future.

Initiatives such as the NGL are critically important to secure a prosperous and sustainable future for Australia and its economy.

**Hon Ian Macfarlane MP  
Minister for Industry and  
Science**

The Western Australian Government, through the Department of Mines and Petroleum, has strongly supported WA:ERA in the development of a National Geosequestration Laboratory based in Western Australia. The NGL is another milestone in Western Australia's drive to become a leading global research and training centre for the energy and resources sector.

CSIRO, The University of Western Australia and Curtin University have a strong track record of collaborative research through WA:ERA since 2003, and now through the NGL they are providing leadership in carbon storage research and best environmental practice.

Western Australia has been active in seeking suitable mainland locations for the geosequestration of carbon dioxide. In the North West, the State hosts the Gorgon Project and its associated massive investment in Carbon Capture and Storage on Barrow Island. My Department is also proud to

be working with the NGL on the South West Hub project investigating the suitability of the Lesueur Formation of the Southern Perth basin for storage of industrial scale CO<sub>2</sub> emissions.

**Hon Bill Marmion MLA  
Western Australian Minister  
for Mines and Petroleum**







# CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) is part of a portfolio of solutions that have the potential to reduce carbon dioxide (CO<sub>2</sub>) emissions. The process involves the capture and deep geological storage (also known as geosequestration) of CO<sub>2</sub> from major industrial sources that would otherwise be emitted to the atmosphere.

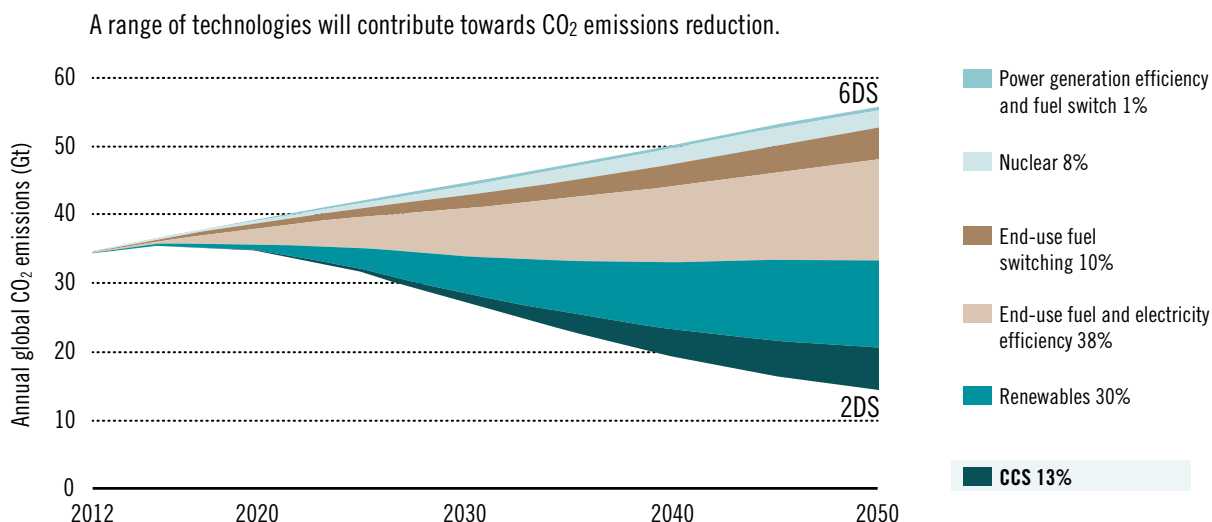
Much of the technology used in CCS is well developed and has been used for decades in the petroleum industry. Experience with geological storage projects across the world has also shown that CO<sub>2</sub> can be stored securely with a very low risk of migration and leakage.

Climate change scenarios suggest keeping carbon dioxide equivalent (CO<sub>2</sub>e) emissions below 450 parts per million (ppm) by 2050 to have a reasonable probability of keeping mean world surface temperature increases under 2°C. The International Energy Agency (IEA) regards CCS as an important contributor to the 2050 target.

The IEA's *Energy Technology Perspectives* 2015 report estimates

that if the 2°C scenario (2DS) target is to be met and not a 6°C business-as-usual alternative (6DS), 13% of the reduction in CO<sub>2</sub>e will come from CCS by 2050. While the efficiency and cost of commercial capture continues to improve, a major role for government and scientists is to undertake research and development to identify and establish viable long term storage sites. Undertaking this research now will provide real options for the future.

The key challenge is how CCS can be used to capture and store industrial emissions at a large scale that is safe and commercially viable.



Source: International Energy Agency, 2015.

# HISTORY OF THE NGL

The Western Australian Energy Research Alliance (WA:ERA) partners CSIRO, The University of Western Australia and Curtin University have a long history of collaboration in the energy and resources sector. Together with the CO2CRC, they also have a significant track record in research and development related to CCS activities; particularly geological storage at laboratory and field scale. So it was fitting that WA:ERA was approached by the WA Department of Mines and Petroleum (WA DMP) in 2010 to become the research partner for its Collie Hub Flagship Project.

The business case for the Collie Hub was successful and the project was renamed the South West Hub Carbon Capture and Storage Flagship Project (South West Hub). In parallel, the Australian Government sought proposals to fund capital equipment linked to the Flagship projects through the Education Investment Fund (EIF). The WA:ERA partners were invited to prepare a bid to establish a National Geosequestration Laboratory (NGL).

The substantial work involved in this proposal was undertaken in a very tight timeframe by key individuals.

In particular, Mr Arno Schaaf, Dr Linda Stalker, Dr Jim Underschultz and Dr Andrew Ross of CSIRO, Professors Boris Gurevich and Brian Evans of Curtin University, Winthrop Professors David Lumley and Eric May of UWA and Mr Mark Stickells then CEO of WA:ERA and now at UWA, were instrumental.

The \$48.4m bid was successful and an EIF funding agreement was signed on 22 February 2012.









# IMPLEMENTATION

The NGL has been structured with an emphasis on subsurface geological research and gas transport. This strategic focus reflects the research strengths of the partners in Western Australia.

Implementation of the NGL, under the leadership of Karl Rodrigues of CSIRO, occurred over a three year period. The EIF funding allowed the NGL to acquire and own equipment that previously had to be sought from third parties across Australia during the CO2CRC Otway Stage 1 testing, so that a complete and dedicated facility could be developed to meet all the needs of carbon storage research.

Throughout the implementation process, health, safety and environment (HSE) requirements of in-field and laboratory facilities were prioritised. This involved aligning federal and state regulation and legislation across the partners to work at the highest common HSE standard.

The result is a facility that spans three sites as well as extensive mobile laboratories, which is attracting significant interest across the world from CCS researchers and the energy and resources industries.





# COMPLETED PROJECTS

Research projects relating to CCS activities and the South West Hub have been underway prior to the NGL facilities being fully commissioned.

## ANLEC R&D Alternatives and Fundamentals program

ANLEC R&D (Australian National Low Emissions Coal Research and Development) has co-sponsored fundamental research relevant to carbon capture, transport, utilisation and storage, with significant cash and in-kind support from the NGL partners. NGL projects include:

- *Pore- and core-scale investigation of CO<sub>2</sub> wettability and residual trapping*
- *Fundamentals of tracer applications to CO<sub>2</sub> storage*

Outcomes from a broad range of projects are available at [www.anlecrd.com.au](http://www.anlecrd.com.au)

## ANLEC R&D Targeted Research program

Further ANLEC R&D projects address specific research questions related to the South West Hub and CarbonNet Flagships and the Surat Basin project.

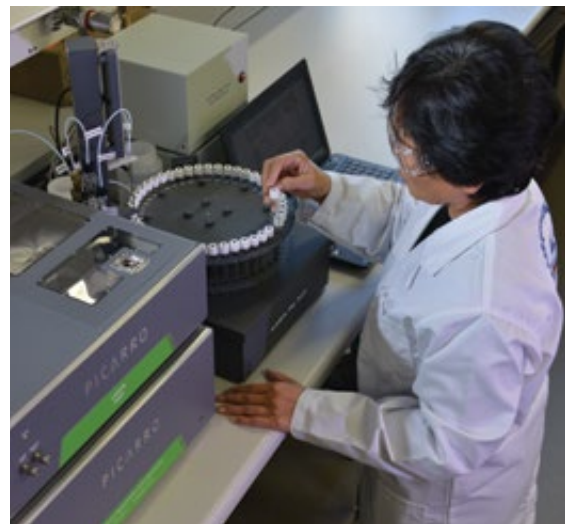
## Site evaluation

Early investigations conducted by the CO2CRC in 2007 and a subsequent review by the Carbon Storage Task Force in 2009 suggested the potential for carbon storage at the South West Hub, with CO<sub>2</sub> sourced from Kwinana and Collie.

This followed earlier evaluation of sites adjacent to the Collie power plants which showed no storage capacity and the area was deemed unacceptable. The research process revealed site characterisation is equally important to confirm geologically unsuitable sites which should not be pursued.

At the South West Hub, investigations have continued and an area now referred to as the Lesueur was identified for further characterisation. This has been a key focus of the NGL's collaborative research with WA DMP.

Defining and delivering these research packages requires close collaboration between the NGL, the Flagships and ANLEC.







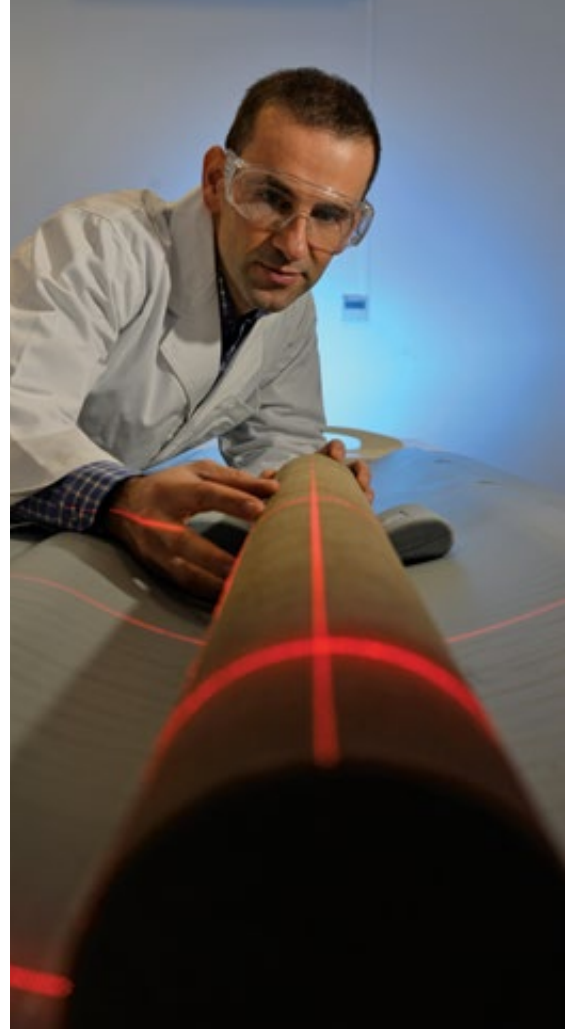
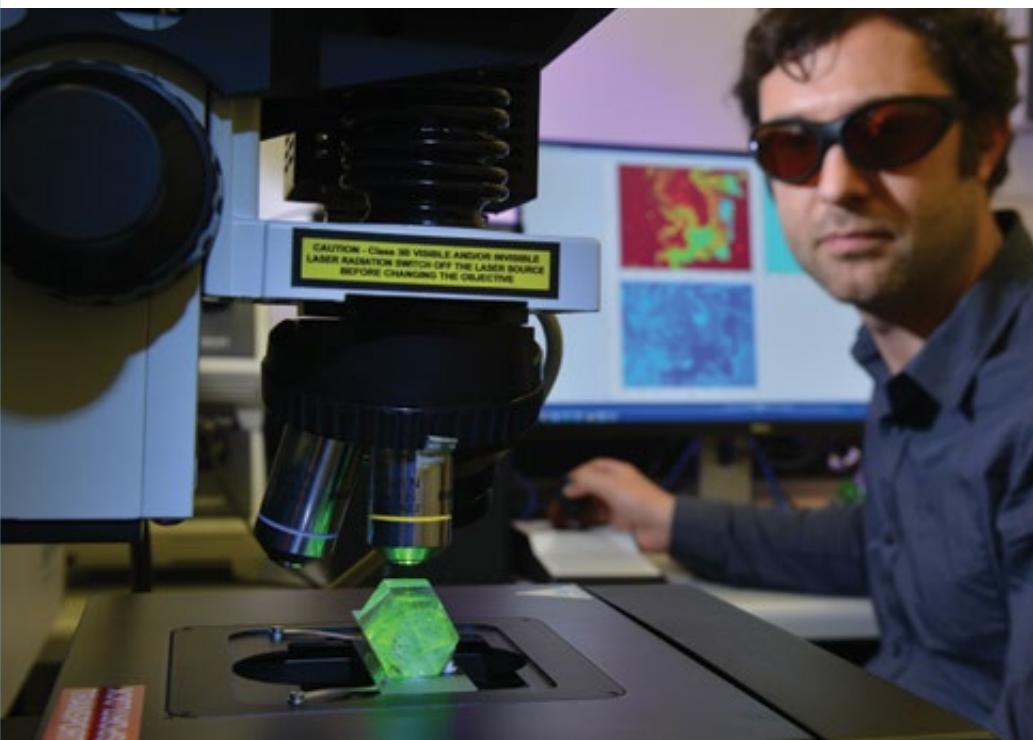
# RESEARCH PRIORITIES

The NGL facility has been created to house a variety of equipment dedicated in the first instance to carbon storage research, development and deployment at commercial scale.

A key priority is to support the South West Hub. Similar support is provided to other CCS Flagships, such as CarbonNet, the broader CCS community, such as Chevron's Gorgon CO<sub>2</sub> Injection Project on Barrow Island, and research at the CO<sub>2</sub>CRC

Otway Project. The NGL also engages internationally with industry and research organisations to provide world class research.

In addition, the majority of the NGL equipment and existing equipment co-located at the three partner institutions has application to the oil and gas sector, mineral resources, water resources and unconventional hydrocarbon exploration and production.



## The NGL has two key purposes:

1. To conduct research to provide certainty regarding the long term safety and commercial viability of CCS
2. To provide education, training and community outreach through sharing knowledge, data and engaging with the public


# RESEARCH CAPABILITIES

The NGL is a complete and dedicated facility to meet the entire needs of carbon storage research. Our capabilities span site characterisation (storage capacity, containment security and injectivity) to performing monitoring and verification activities and field trials and tests.



The primary role of carbon storage research is to provide certainty of the viability and safety of large scale geological storage of CO<sub>2</sub>.





**Containment security** research involves evaluating the geology to determine whether the CO<sub>2</sub> will be confined to the zone in which it is injected.

- Identifying barriers and seals
- Understanding fault properties and geometry
- Modelling migration pathways
- Chemical tracers are used to acquire more information about migration behaviour and potential leakage (CASE STUDY 1)

**Storage capacity** research involves defining the amount of CO<sub>2</sub> which can be stored at a given site.

- Geophysical data acquisition, processing and interpretation
- Rock characterisation to understand porosity and permeability of the storage site
- Seismic trucks are used to provide high resolution images of the subsurface geology for estimating storage volume of the reservoir (CASE STUDY 2)

**Injectivity** research involves estimating the rate at which CO<sub>2</sub> can be injected into the subsurface and migrate away from the injection site.

- Rock characterisation, core flooding and imaging
- Geochemical behaviour of the rock on contact with CO<sub>2</sub>
- Geomechanical testing is used to evaluate the strength of the rock during injection (CASE STUDY 4)

**Transport and gas processing** research involves investigating the most efficient, cost effective and safe way to process and transport CO<sub>2</sub> to the storage site and how the CO<sub>2</sub> interacts with impurities before and after injection.

- Understanding fluid behaviour in pipelines
- Characterising the composition of the transported gas
- Geo-reactors are used to test the impact of CO<sub>2</sub> on ageing materials such as infrastructure and geology (CASE STUDY 6)

**Monitoring and verification** programs involve undertaking monitoring before, during and after injection to ensure CO<sub>2</sub> is stored safely. This data verifies predictions made before injection and is used to inform regulators.

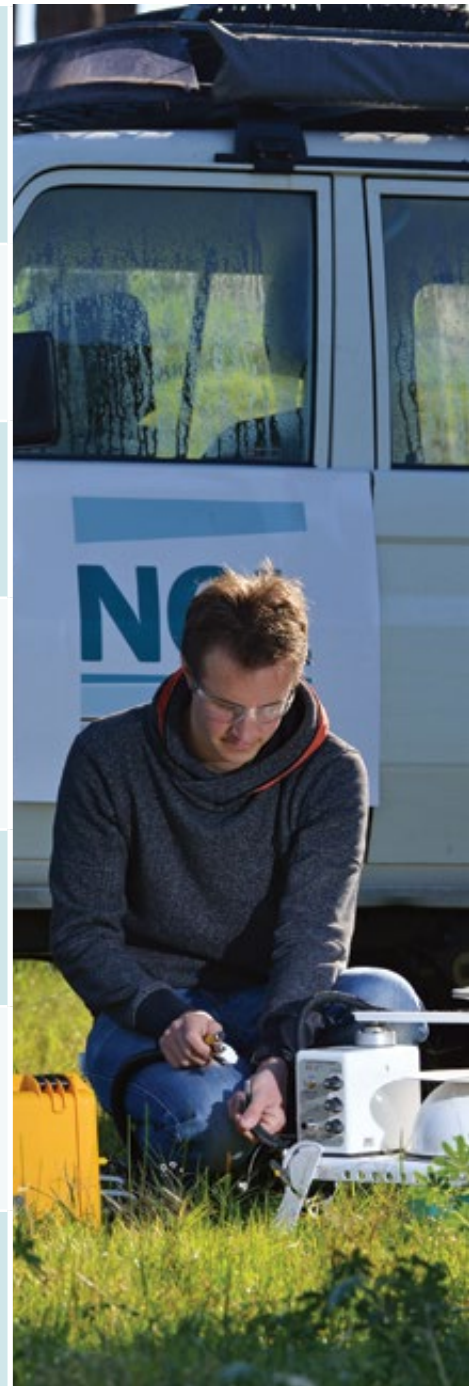
- Baseline and environmental variation monitoring over the project lifetime (>50 years)
- Passive seismic monitoring to investigate the potential for long term CO<sub>2</sub> imaging
- A suite of equipment is used for atmospheric, groundwater and soil-gas monitoring (CASE STUDY 7)

**Education and training** programs include unique training facilities to allow hands-on experience in site characterisation and testing of equipment in a controlled environment prior to field deployment.

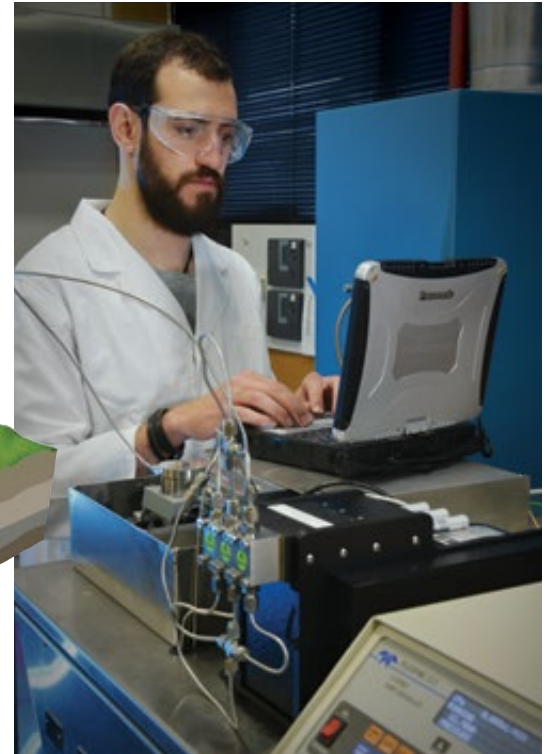
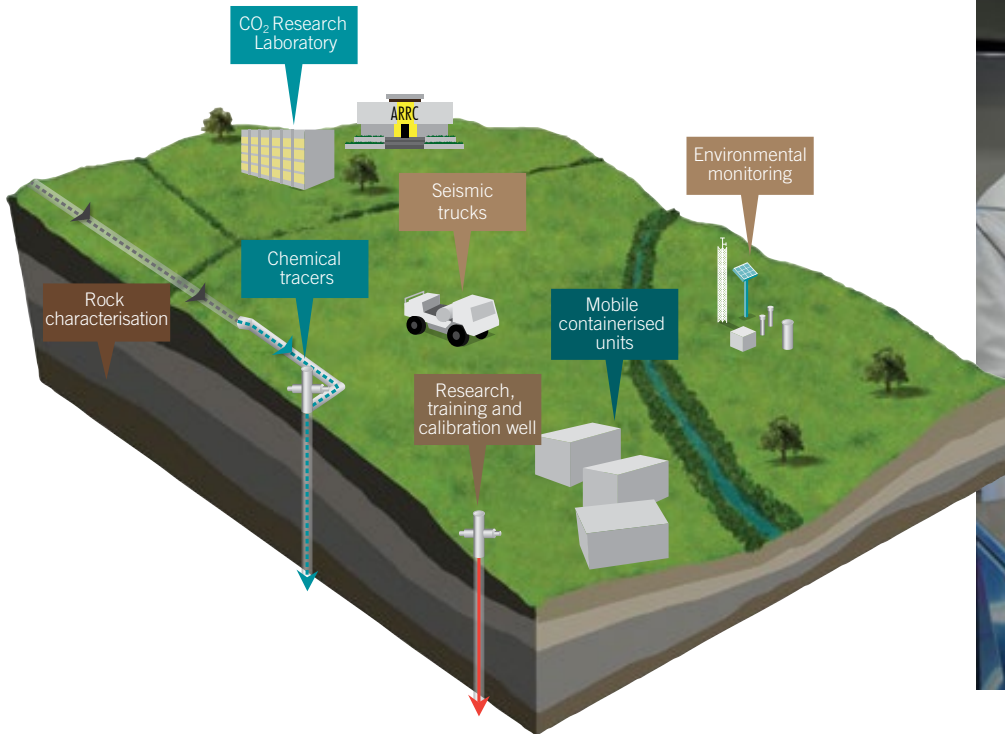
- Research, calibration and training well (CASE STUDY 5)
- Transport and gas processing studies at the CO<sub>2</sub> Research Laboratory
- Creating university research, education and training programs to enhance capacity in CO<sub>2</sub> storage science and engineering

**Public awareness and community outreach** includes community engagement to inform and educate stakeholders and share knowledge.

- Developing informative materials to support CCS project engagement
- CarbonKids/Sustainable Futures school and community outreach
- Acting as trusted advisor for community, government and industry



# CASE STUDIES



## 1. Chemical tracers

Chemical tracers have been used extensively by NGL staff in field deployment at the CO2CRC Otway Project and in research for other organisations. They are useful to understand migration and dispersion of CO<sub>2</sub> in the subsurface.

However in the past it has been difficult to make detailed measurements of how much of a chemical tracer may partition (also known as partition coefficients) into the supercritical CO<sub>2</sub> phase and

how much might stay in the formation water phase at reservoir temperature and pressure. So NGL has redesigned and modified its batch reactor apparatus for measuring partitioning coefficients to improve understanding of tracer behaviour.

The modifications include replacing all CO<sub>2</sub> wetted parts with more resistant materials to minimise corrosion. The laboratory also uses a slim-tube flow cell to measure and monitor chemical tracers on different rocks and mineral surfaces to investigate

how much tracer might be lost during migration of CO<sub>2</sub> through different rock types in the subsurface.

The new facility is part of a strategy to evaluate chemical tracers for use in CCS and other purposes, such as monitoring groundwater, natural gas, or oil for enhanced recovery. Integrating laboratory data with analysis from field deployment is part of an overall workflow for testing chemical tracers in which numerical modelling plays a significant role.





## 2. Seismic trucks for site screening and monitoring

The NGL's two new compact seismic trucks allow scientists to conduct 4D seismic surveys and smaller scale high resolution surveys. The availability of the trucks to researchers allows greater consistency between surveys, producing more accurate data, which is essential for monitoring the migration of the CO<sub>2</sub> over time and reporting conformance to regulators in onshore environments where time-lapse seismic is more difficult to achieve.

A seismic survey uses vibrations to produce detailed images of rock layers underground.

Another benefit is that the trucks are smaller than commercial seismic trucks, which allows them to access normal roads, and they can be fitted with floatation tyres to significantly reduce impact to farmland and other ecosystems. The trucks can also be used in tandem to increase signal strength underground.

The trucks have already completed a 'nested' 3D seismic survey at the Harvey-4 well which produced high resolution data providing better accuracy on the location, length and orientation of nearby faults and the formations they intersect.

This has helped researchers understand potential compartments or blocks where the CO<sub>2</sub> might reside during injection and gain a better insight into the surrounding fault properties; whether they are sealing, or open, which might allow CO<sub>2</sub> to migrate between blocks.



### 3. Mobile containerised laboratories

Three new mobile containerised laboratories allow NGL researchers to conduct accurate and timely research in the field.

Each container is fully equipped with a high level of safety certification for on and offshore use. Air conditioning and flexible power options allow analytical equipment and computing hardware to be operated in a stable electrical environment in any location.

The *analytical laboratory* hosts geochemical equipment and mass spectrometers to measure

concentrations and isotopes of CO<sub>2</sub> and CH<sub>4</sub> and analyse gases and chemical tracers. A U-tube sampler can take pressurised fluid samples from a deep well onsite to more accurately analyse them for CO<sub>2</sub> and pH levels.

The *wet chemistry laboratory* allows other analyses and processing of samples from monitoring surveys, subsampling of fluids from depth, or conducting basic tests on groundwater samples. A built-in fume hood can be used for sensitive sample preparation.

The *data and communications centre* records and preserves all data. This includes data collected from the chemical laboratories and geophysical

and physical data collected from adjacent wells installed with downhole instrumentation.

The three laboratories are part of a larger body of equipment that includes generators, geochemical, geophysical, and environmental monitoring equipment.

The design of the equipment is based on previous experience with field deployments at the CO<sub>2</sub>CRC Otway Project and the Gulf of Mexico oil spill to ensure the laboratories are suitable for multi-purpose use at different sites.



#### 4. Rock characterisation

New equipment has been commissioned by the NGL to complement the existing rock mechanics capability.

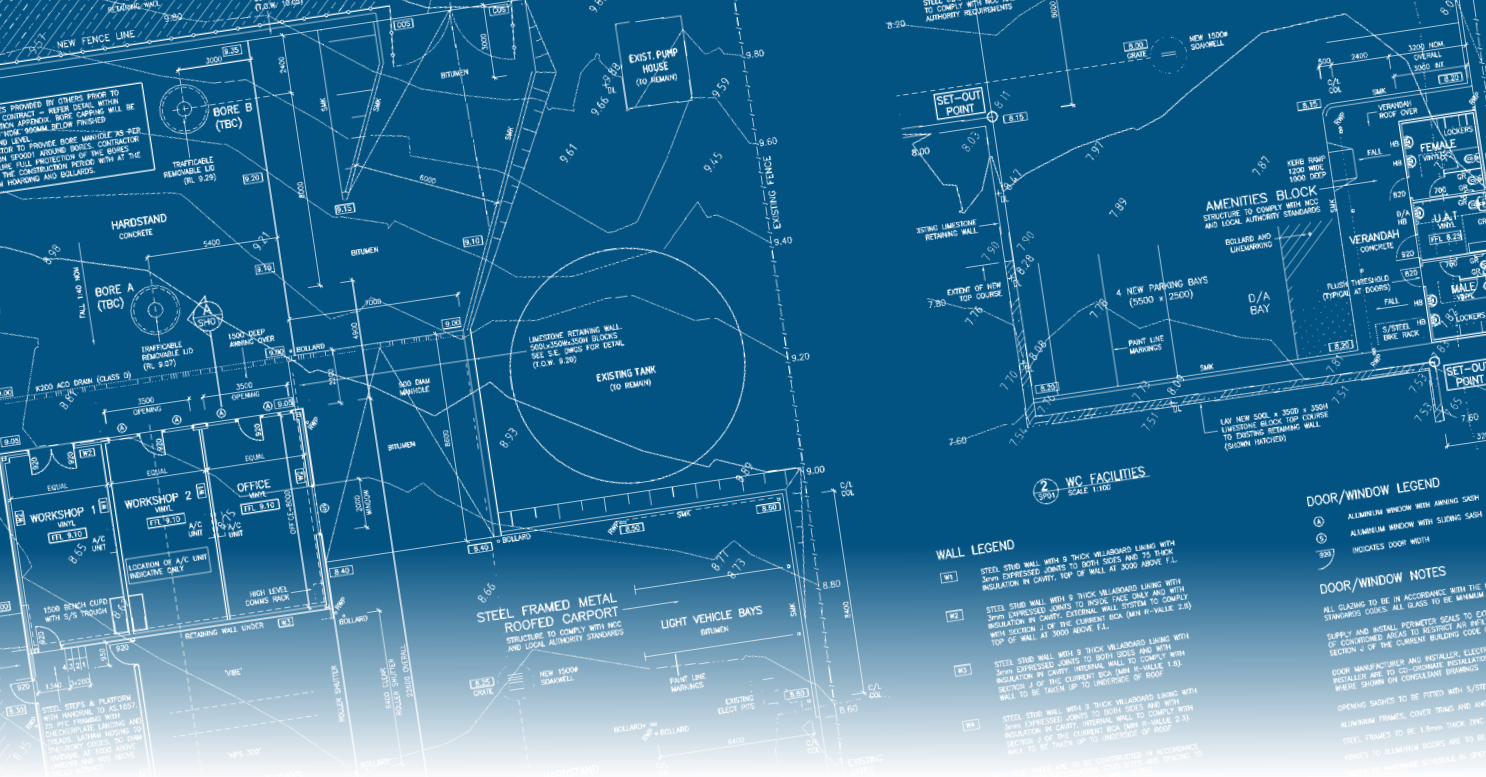
New autonomous triaxial cells (ATCs) have been re-designed to deal with the challenges of working with supercritical CO<sub>2</sub>. The ATCs house core samples which can be heated and compressed to replicate reservoir conditions and can undergo a series of tests to evaluate strength and other rock properties in the presence of supercritical CO<sub>2</sub>.

The data are used to better understand how rocks behave in the deep subsurface. The information can also be compared with field data from seismic methods to better predict the rock properties and improve mapping of the rocks in the subsurface.

The data are also used to design and develop models for estimating how CO<sub>2</sub> will migrate through the subsurface and whether the location of the CO<sub>2</sub> plume can be identified remotely via seismic surveys. By testing in the ATCs we can better determine if the rock properties change before and after the CO<sub>2</sub> arrives so we can map the movement of the CO<sub>2</sub> and report to regulators that we understand its behaviour and movement in the subsurface.

True Triaxial Stress Cells (TTSCs) are similar to ATCs but allow researchers to test rock properties using larger cubes of rock (up to 300mm) that can be stressed in three different orientations. This provides a more realistic stress regime. Moving to larger scale tests is an ongoing challenge in geoscience but new technology such as TTSCs can improve our knowledge through controlled laboratory experiments and modelling to compare results from a range of situations.





## 5. Research, training and calibration well

As a part of the NGL's research and education program, a 900m calibration and training well has been drilled at the Curtin University campus.

The well is completed with plastic casing to allow conventional methods of wire line logging as well as electromagnetic methods to be deployed without interference. Plastic screens allow direct contact with the rock surface and fluid samples to be taken.

The facility provides unprecedented access to a well in an urban location allowing researchers to calibrate equipment before being deployed to remote settings or in expensively completed commercial wells.

New tools and methods for logging can also be trialled, compared and evaluated against results from conventional equipment.

As a training facility, the well provides hands-on experience to geoscience, geophysics and engineering students. Students and researchers are trained to deploy equipment, retrieve data and overcome technical problems before using deeper and narrower wells in the field.

An adjacent storage facility houses various survey equipment such as geophones and sensors, a logging truck and the NGL's seismic trucks which can also be used during testing at the well.

## 6. CO<sub>2</sub> Research Laboratory

The CO<sub>2</sub> Research Laboratory at The University of Western Australia is a purpose built facility to house:

- CO<sub>2</sub> processing equipment
- near-surface seismic equipment
- a fluidised bed reactor and geo-reactors
- teaching spaces and facilities for students and graduate researchers.

Equipment includes geo-reactors designed to conduct high temperature, high pressure experiments to evaluate the impact of supercritical CO<sub>2</sub> on different rock and mineral types at varying temperatures over time. This allows us to understand the long term effects of CO<sub>2</sub> on seals above the reservoir which cannot be determined in the field under normal timescales.



The geophysical monitoring equipment is stored onsite to allow testing and training before deployment. It includes mobile survey equipment and passive seismic equipment used for monitoring near-surface environments for mineral exploration, agriculture and archaeological activities.

## 7. Environmental monitoring

Environmental monitoring is an essential component of the monitoring and verification process. It is used to establish baseline data, and for risk-based monitoring. The NGL has a comprehensive suite of monitoring equipment which is used to measure concentrations of CO<sub>2</sub> and other gases in the atmosphere, soil and groundwater.

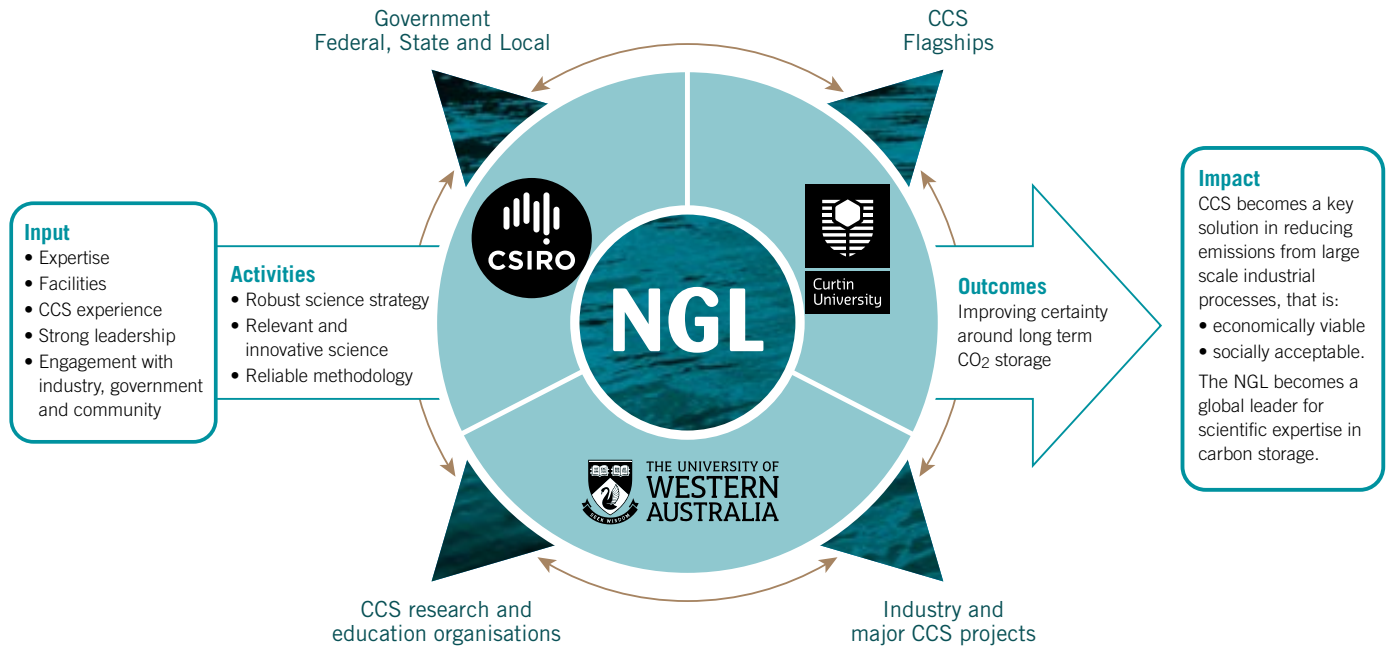
The equipment is deployed throughout the carbon storage process from site characterisation to injection and post-injection.

Passive seismic monitoring is also used to determine baseline rates and strengths of naturally occurring seismic events. Passive seismic sensors can then be used to measure any additional seismic activity induced during injection of the gas.

A range of techniques for atmospheric and soil-gas monitoring have been compared at the Ginninderra Shallow Release Site in Canberra. Reducing CO<sub>2</sub> emissions in the atmosphere is a key driver of carbon storage research. Thus being able to accurately measure atmospheric concentrations of CO<sub>2</sub> at the field site is an important part of the assurance monitoring program to demonstrate safe storage of CO<sub>2</sub>.



# DOING BUSINESS WITH THE NGL



The NGL research facility provides tools and methods to assist decision-making for CCS activities in Australia and overseas. It offers opportunities for large scale collaboration on a local, national and international scale between government, industry and the community.

The NGL offers an integrated pathway across the entire value chain of carbon storage, from providing instrumentation and technicians to interpretation of data

and delivery of results. We are a one-stop shop.

A fully integrated laboratory information management system ensures samples can be taken through multiple stages of the research process, from geochemistry to rock characterisation, and deliver clear and consistent results. Chain-of-custody methods are also established for the movement of equipment and samples around the facilities.

We can conduct service based research on a commercial basis for industry clients, service companies, government organisations and research institutions. Projects can be commissioned as jointly funded collaborations or as fee-for-service contracts depending on the nature of the work.

Such research extends to our fundamental expertise in oil, gas and unconventional exploration and production, mining and oil spill response.





**Contact us to discuss how we can work with you.**

Linda Stalker  
NGL Science Director  
Email: [linda.stalker@csiro.au](mailto:linda.stalker@csiro.au)  
Phone: 08 6436 8909



**NGL Project Director**  
Mr Karl Rodrigues

**NGL Science Director**  
Dr Linda Stalker

**NGL Operations Manager**  
Dr Lionel Glendenning

**NGL Science Committee**  
Dr Linda Stalker, CSIRO (Chair)  
Dr Lincoln Paterson, CSIRO  
Mr Karl Rodrigues, CSIRO  
Dr Steve Whittaker, CSIRO  
Prof David Lumley, UWA  
Prof Eric May, UWA  
Prof Brian Evans, Curtin  
Prof Boris Gurevich, Curtin  
Mr Kym Bills, WA:ERA  
Dr Lionel Glendenning, WA:ERA

**Contact**

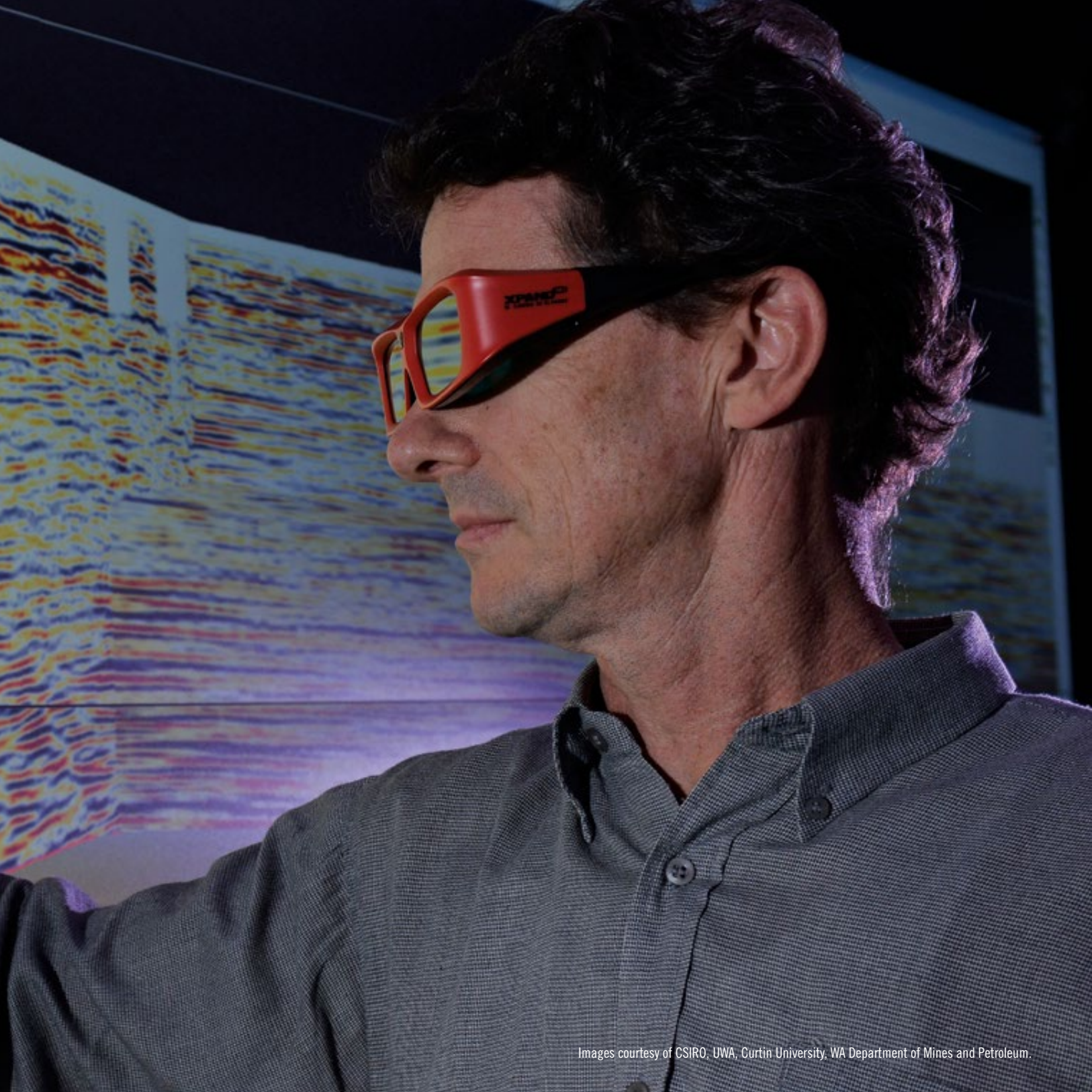
Web: [ngl.org.au](http://ngl.org.au)

Email: [linda.stalker@csiro.au](mailto:linda.stalker@csiro.au)

Phone: 08 6436 8909







Images courtesy of CSIRO, UWA, Curtin University, WA Department of Mines and Petroleum.

# National Geosequestration Laboratory

The National Geosequestration Laboratory was awarded \$48.4 million by the Australian Government through the Education Investment Fund to build infrastructure and procure laboratory and field equipment to support the South West Hub Carbon Capture and Storage Flagship Project and other national and international CCS projects.

