Future Fuels CRC achievements and Future research goals for renewable gases

FENEX CRC May 2025

David Norman - CEO

Today's Presentation

1) **Overview of the Future Fuels CRC**
   A proactive community focused on the enabling infrastructure needs of hydrogen (and other renewable fuels)

2) **Key achievements from Future Fuels CRC**

3) **Research Dissemination and Translation**

4) **Transition to Gas Infrastructure Research Australia**

5) **Future Research Focus Areas to highlight**

Mechanical testing of pipelines in H2 environment- University of Wollongong

Industry-Led, Outcomes Focused, Applied Research

Mission, consistent since 2018:

- **Through collaboration and outcome focused research, we will enable Australia's energy sector to adapt its infrastructure to net zero emissions fuels by providing new knowledge and facilitating its use by industry.**

118 projects and **50 PhD and Masters** scholarships covering:

- **Future Fuel Technologies, Systems and Markets**
- **Social Acceptance, Public Safety, Security of Supply and Policy & Regulatory Changes**
- **Network Lifecycle Management**

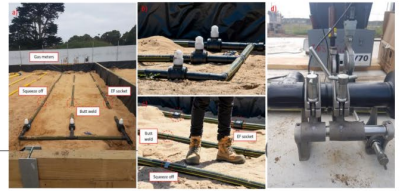
Australian Government
Department of Industry, Science, Energy and Resources

Business Cooperative Research Centres Program

APGA Australian Pipelines & Gas Association
Energy Networks Australia
GAMAA
SOUTH AUSTRALIA
energysafe VICTORIA
Jemena
Australian Gas Infrastructure Group
THE UNIVERSITY of ADELAIDE
RMIT UNIVERSITY
THE UNIVERSITY OF QUEENSLAND AUSTRALIA
Queensland Government
NSW GOVERNMENT
DEAKIN UNIVERSITY AUSTRALIA
UNIVERSITY OF WOLLONGONG AUSTRALIA
THE UNIVERSITY OF MELBOURNE

Domestic testing capabilities

- Deakin: Corrosion testing, polymer pipe testing, APT
- UoM: Appliance testing, coating testing, polymer pipe testing
- UOW: Pipe materials testing (in gaseous hydrogen), HDD impact testing
- UoA: Appliance testing
- UQ: Pipe materials testing (electrochemically charged specimens)
- Full scale pipe burst test testing facility (in progress)

Our regular international linkages

Emerging Fuels MOU – APGA, EPRG, FFCRC, GERG, GTI & PRCI
CEO Forum has moved to 2 WG's – Materials and Design and Inspection & Integrity

International Collaborations Cont'd

Other collaborations:

- National Grid (UK): Knowledge exchange on Future Grid test facility
- GasUnie (NL): Knowledge exchange on practical pipe conversion issues
- IGEM (UK): Standards and code of practice (pipelines, networks, appliances)
- Sandia National Lab (US): pipe and network material testing in hydrogen
- PRCI Emerging Fuels Institute (US): Internal coatings / full scale testing
- GERG / ThyGa: Appliance testing
- EPRG: Lab scale and full scale hydrogen testing
- Nova Chemical (CAN): Shock tube testing
- DNV (NOR / US): Tensile strain capacity/ In-service welding of H2 pipelines
- DNV (US): University or Regensburg (GER): CO2 pipeline modelling

FFCRC Overview

118 Projects across the Future Fuels CRC
(85 Completed, $29mln cash, over $60mln total with in-kind)

RP1: Future Fuel Technologies, Systems and Markets

40 Projects

- End use appliance testing: both domestic and Industrial furnaces
- New and novel manufacturing techniques, e.g. Methane Pyrolysis, Solar Catalysis
- Technoeconomic modelling the value of large-scale hydrogen storage integrated into the energy system

RP2: Social Acceptance, public safety and security of supply

25 Projects

- Understanding householder energy usage
- Citizens Panels in 5 locations, Public communication and social license of hydrogen
- Regulatory mapping of future fuels, Understanding the impact of a Renewable gas target in Australia
- Public Safety Assurance for Future Fuels in the Energy Transition, Risk Governance in Procurement
- Avoidance of external pipeline damage, 3rd party interference, HDD test rig

RP3: Design, construction, and operations and decommissioning

53 Projects

- Plastics, distribution assets, elastomers
- Metals – Hydrogen Embrittlement, Fracture Toughness and Fatigue Testing, Welding
- Integrity, Corrosion, Cathodic Protection, Coatings, Offshore Piping
- H2 Pipelines Code of Practice, Ammonia Pipelines, CO2 Pipelines, H2 Ready Pipelines

Plastics research at Deakin University

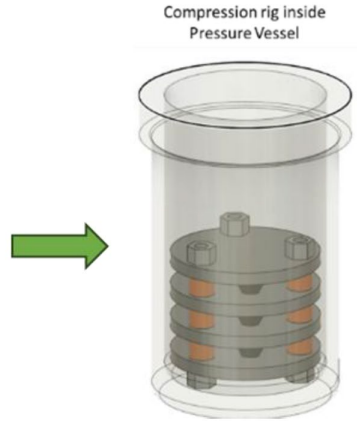
Long-term sandpit environment representing Australian ‘as-installed’ plastics networks

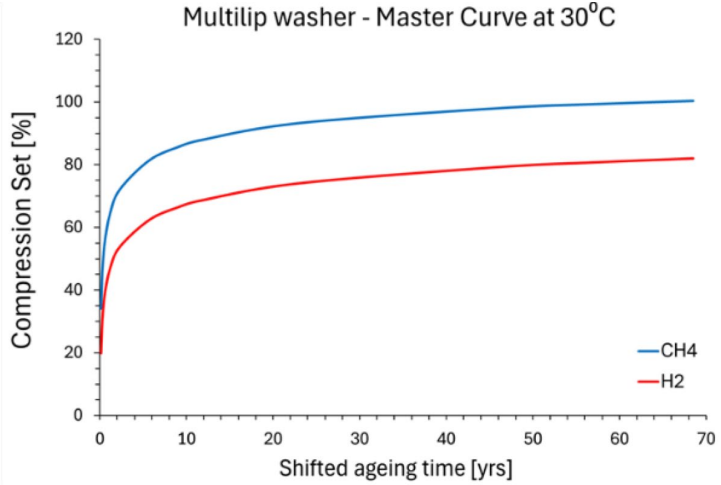
Laboratory testing of plastics and elastomers with hydrogen

Hydrogen & elastomers

RP3.1-14 – recently completed

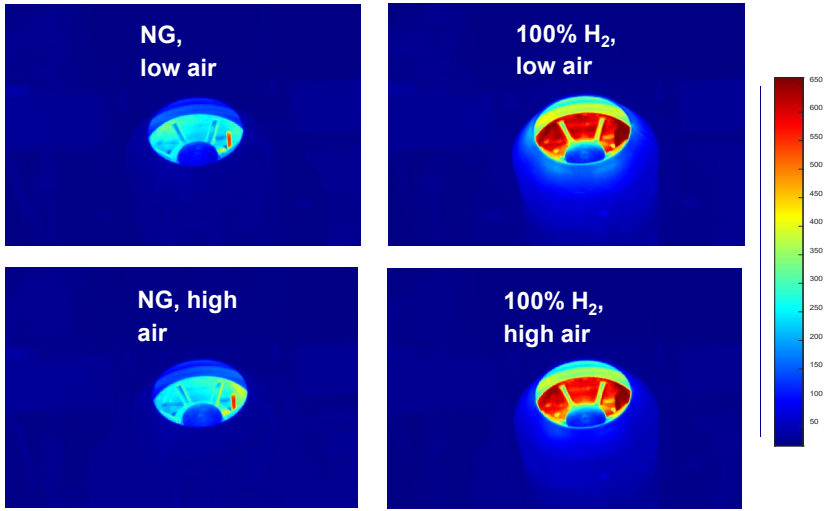
- Phase B: detailed testing for a selection of elastomers following industry consultation
- Several tests (chemical degradation & mechanical response) following exposure to both CH_4 and H_2
- Temperature-accelerated tests to predict behaviour over several years
- Changes in degradation kinetics observed – lower CS% in H2 vs CH4 indicates improved performance for hydrogen
- However, H2 may lead to increased stiffness which could impact performance
- Possible future research to correlate with service life

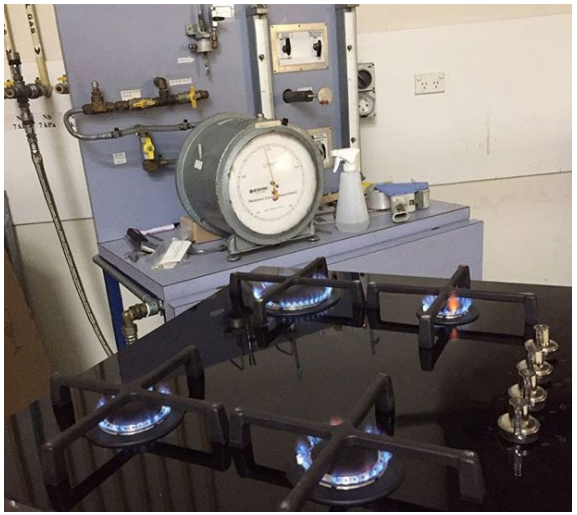




10 appliance research projects

Supporting long-term safety cases for hydrogen blending and appliance conversion to 100% H_2 in Type A and Type B appliances

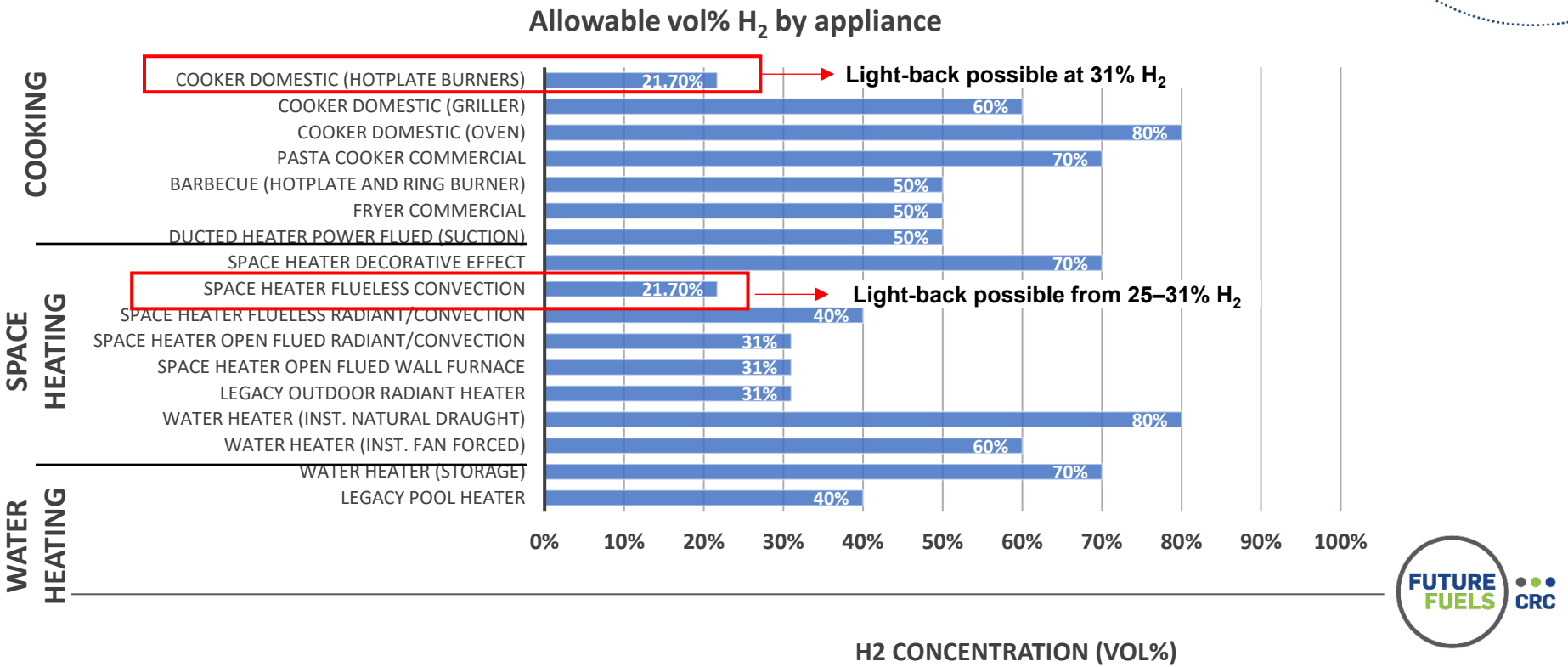




Overall Results – Type A

Maximum H_2 concentration (no changes)

* Values shown in graph correspond to the highest blend % at which an issue/limiting factor did **not** occur



Overall Results – Type B Testing

Summary of results: (a) no changes and (b) "normal adjustments"

(a)

Burner tested	Max H_2 [%]	Reason/observation
AN burner (open)	55	Light back at low rate
AN burner (closed)	80	Flame detection (flame rod)
Package burner	99	Flame detection (flame rod) – possibly lower limit (overheating)
High-velocity burner	100	No issues in flame detection or stability
Air-heat burner	40-50	Over-heating
Radiant burner*	40	High probability of light back on ignition

(b)

Burner tested	Max H_2 [%]	Change made	Reason/observation
AN burner (open)	70	Constant heat input of 35 kW	Light back
AN burner (closed)	100	Flame rod replaced by UV sensor	No limit observed
Package burner	100	Flame rod replaced by UV sensor	Overheating may be a concern
High-velocity burner	100	No change necessary	No limit observed
Air-heat burner	40-50	No change made	Overheating
Radiant burner*	40	No adjustment feasible	High probability of light back (ignition)

Note: Radiant burner is a Type A appliance, but similar to other Type B designs

FFCRC Key Achievements – Real World Progress

Western Sydney Green Hydrogen Hub

Hydrogen Park South Australia

ATCO Hydrogen Community Blending

Hydrogen Park Gladstone

Malabar Biomethane Injection Plant

Hydrogen Park Murray Valley

Aust – Largest Hydrogen Plants In Operation

Project	Company	Size (MW)	State	Year	APGA	Comments
Hydrogen Park South Australia	AGIG	1.25	SA	2021	✓	
Christmas Creek Renewable Hydrogen Mobility Project	FMG	2 x 0.7	WA	2024		* Is this site actually operating beyond a commissioning run? Link with LH2 plant?
Hydrogen Production and Research Facility	Blue Economy CRC	0.7	Tas	2025		Commissioned but regular throughput unclear
Western Sydney Green Gas Prj	Jemena	0.5	NSW	2021	✓	
Denham Hydrogen Demonstration Plant	Horizon	0.348	WA	2024		
Clean Energy Innovation Hub	ATCO	0.26	WA	2019	✓	
Toyota Ecopark Hydrogen Demonstration	Toyota	0.25	Vic	2021		
Renewable Hydrogen Production and Refuelling	BOC Ltd	0.22	QLD	2022		
Hydrogen Park Gladstone	AGIG	0.175	Qld	2024	✓	
Canberra H2 Refuelling Station	Pacific Energy	0.075	ACT	2021		
CSIRO H2 Refuelling Station	CSIRO / Swinburne	0.06	Vic	2023		

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Aust - Hydrogen Plants In Construction

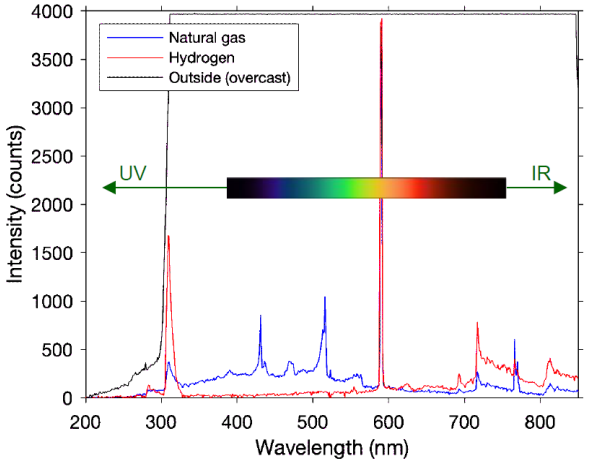
Project	Company	Size (MW)	State	Year S/U	APGA Link	Comment
Gladstone PEM Project	FMG	30 (Phase 1)	Qld	2025		* Is this site genuinely in construction phase at this scale?
Hydrogen Park Murray Valley	AGIG	10	Vic	2025	✓	
Yurie – Yara NH3	ENGIE	10	WA	2025		
Geelong – New Energy Station Project	Viva Energy	2.5	Vic	2025	✓	
Sumitomo Green Hydrogen Pilot	RIO	2.5	Qld	2025		
Goondiwindi Hydrogen	Goondiwindi	1	Qld	2025		
SunHQ	Ark Energy	1	Qld	2025		
Kogan Creek Demo Plant	CS Energy	1	Qld	2025		

Source – HyResource – www.research.csiro.au/hyresource - data and listing as at April 2025

RP1.4-10 (H_2 Flame Visibility)

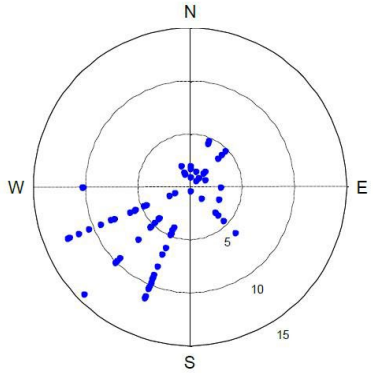
Understanding source of yellow-orange colour & implications

Flame spectrometry

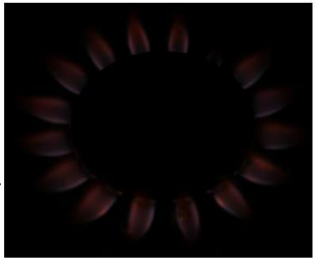


Approx. λ (nm)	Origin
310 (and 285)	OH*
430	CH*
515	C_2 Swan bands
589	Na
Visible continuum (400-700)	Soot and/or CO_2*
IR continuum (>700)	H_2O* (with some CO_2* peaks)

Impact of environmental conditions (wind direction)



LHS & middle → H2 (diff. days)
RHS → NG



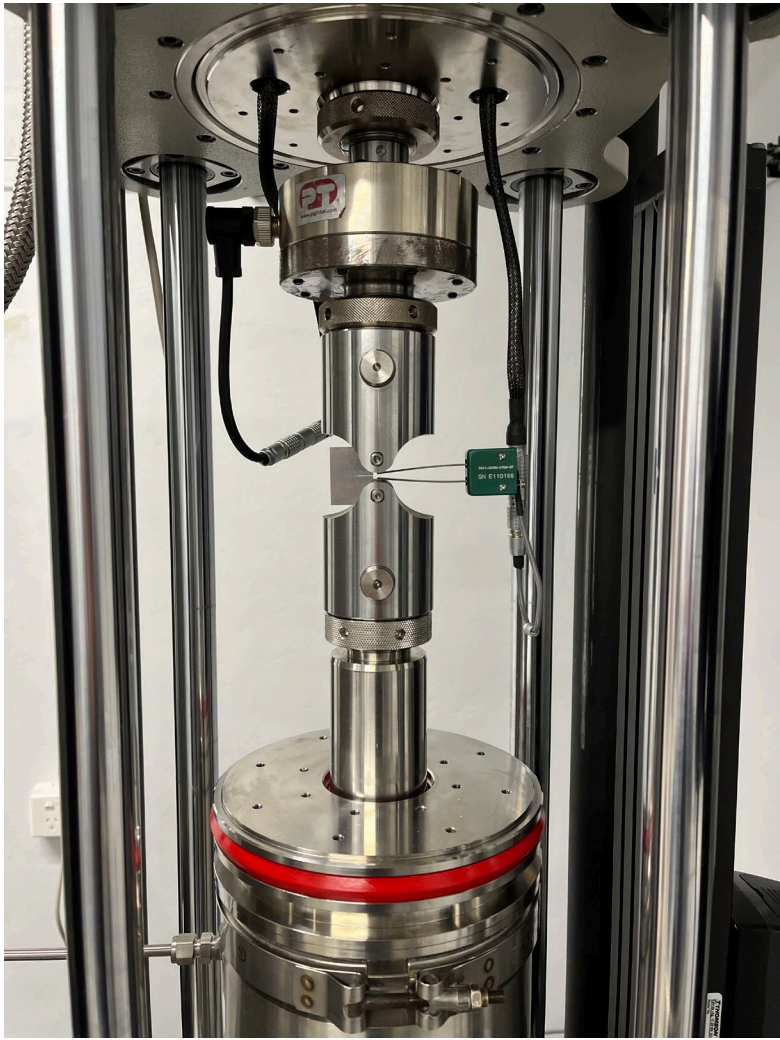
Steels Research: tensile testing in hydrogen

- SafeTi Lab at the University of Wollongong
  - Overseas Labs now with years of testing backlog
  - Crucial to ASME B31-12 Option B pathways
- Longer-term commercialisation in progress to provide testing asset for Australian industry
- Hydrogen embrittlement, Tensile strain
- Fracture initiation and propagation
- APA Parmelia Gas Pipeline assessment
- Hydrogen Pipeline Code of Practice

RP3.1-12 Gaseous H_2 testing of representative Australian pipelines

Project purpose and scope

- *Builds up on RP3.1-09: Deployment of the H2SAFE(TI) Lab*
  - *An infrastructure with 3 gaseous H_2 testing machines up to 500 kN load and 15 MPag pressure, now operated by Rosen*
- Brings international testing know-how to Australia, capitalises expertise, involved with international laboratories in the developments of gaseous H_2 testing & standardisation
- Assess material properties in air and hydrogen for 8 representative Australian line pipes and 1 sour service



RP3.1-12 Gaseous H_2 testing of representative Australian pipelines

Provided Line pipes

- 9 pipes for test program
- Grades from X52 to X70
- Years from 1980 to 2021
- Test program:
- Tensile test (Air, H2)
- Fracture toughness (Air, H2)
- Charpy tests (Air)
- Base metal in transverse direction
- Tests on similar material done at UQ with Electrochemical charging
- Air characterisation delivered in previous milestone

FFCRC lab-scale testing of pipeline steels

Overview and work to date:

- Parallel research/testing: **UoW/Rosen SAFE(TI) lab** (gaseous H_2) and **UQ cathodic charging**
- Focus is on understanding changes in material properties (esp. fracture toughness)
- UQ research: Final Report on HE testing of X65 available via website (RP3.1-10)
- SAFE(TI) lab: Testing 9 different Australian pipeline steels in pressurised H_2 (RP3.1-12)

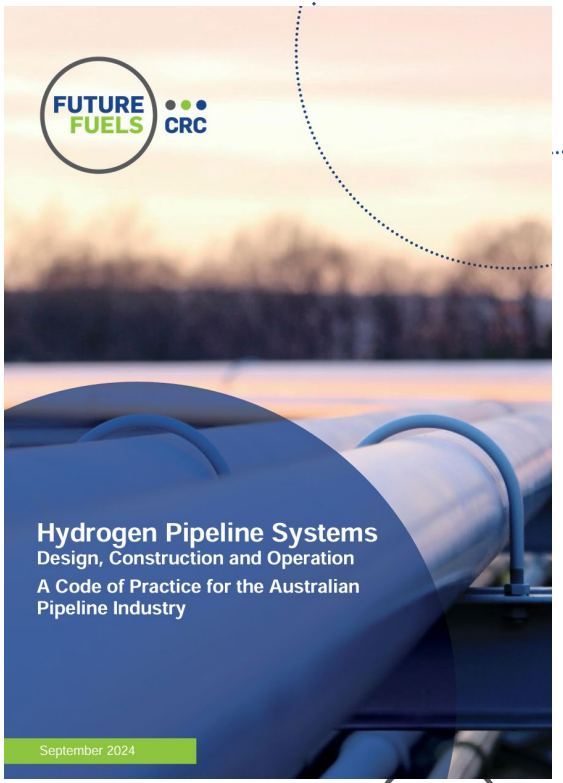
Ongoing work and next steps:

- Comparison of results from two labs is in progress – workshop to be held in May
- Work is ongoing to understand the impact of trace O_2 on test method and results (current source of uncertainty for UoW testing)
- Hydrogen-induced subcritical cracking → possible future research topic (but not observed from tests to date)
- Ongoing collaboration with international labs and researchers
  - **PRCI/EFI full-scale testing in H2 (FFCRC-supported project)**

H2 Pipelines Code of Practice

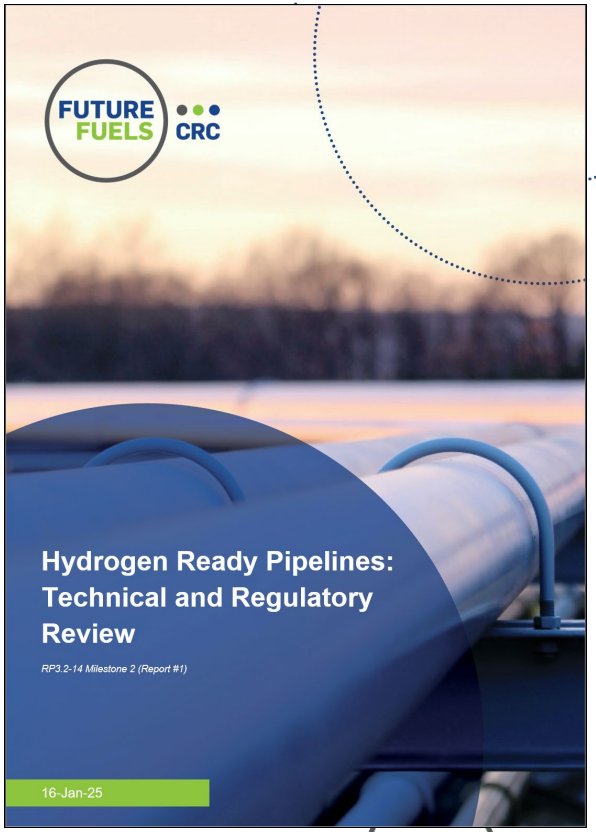
- Recently held APGA Seminar to launch the Code of Practice
- Official handover from FFCRC to APGA to occur in coming weeks
- Will include revision and publication via APGA website
- Expect future revisions required as industry knowledge continues to develop

Link to APGA CoP Seminar presentations



FFCRC Key Achievements - Hydrogen Ready Pipelines

- Focus is on new pipelines designed for natural gas, with consideration for hydrogen
- H2-ready considerations split into 5 sections:
  1. *The operating envelope—considering the effect of hydrogen on the material properties of the steel line-pipe and weld/HAZ*
  2. *The requirements for materials testing of the pipeline steel (line-pipe and girth-welds/HAZ) for hydrogen service*
  3. *The hydrogen compatibility of components, equipment, instrumentation and operational procedures used in the pipeline system*
  4. *Impact of hydrogen on likelihood and consequence of failure (in the context of pipeline safety management as per AS 2885.6)*
  5. *The suitability of the Pipeline Integrity Management Plan (PIMP) for hydrogen service*
- Developing “summary table” following feedback from advisors



Driving research translation

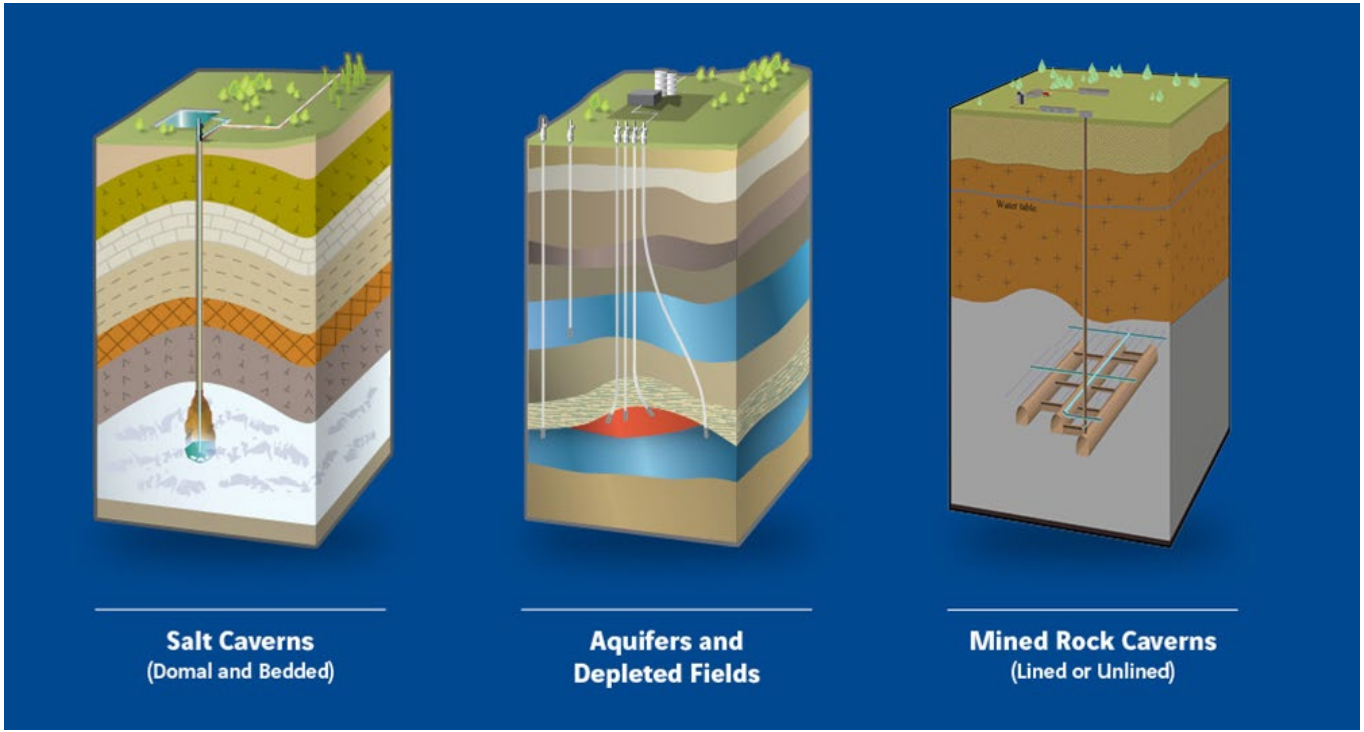
- **261+ reports, 77 Journal papers, 20 PhD Thesis on website members' area**
- Face to face events with industry, seminars and conferences
- Working Groups and Steering Committees
- Over 50 webinars, seminars and conferences so far
- Members website and email research update
- Over 100 key stakeholder info sharing partners
- Commercialisation and translation of IP to industry, 10 Patents

Future research with GIRA

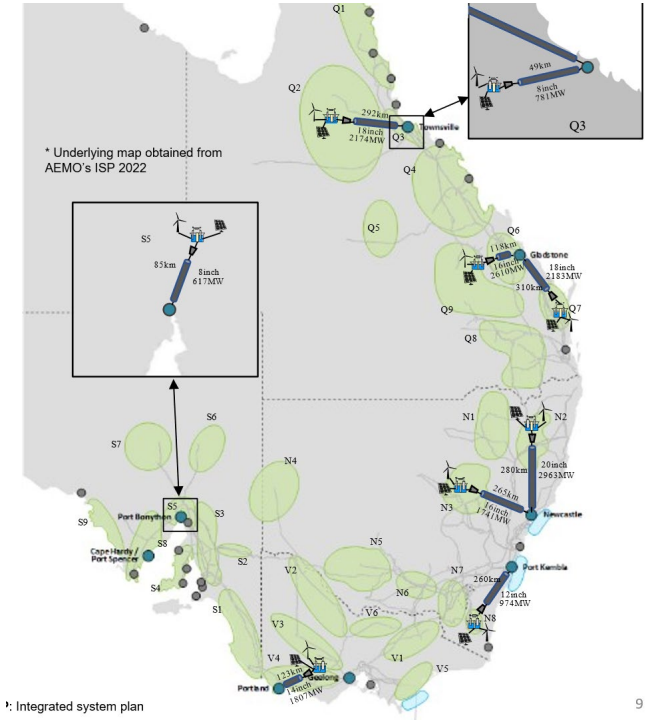
- Gas Infrastructure Research Australia (GIRA) will take on future research for the industry.
- APGA and ENA working to finalise GIRA constitution and Service Agreement
- GIRA is the new industry-led organisation that funds and manages applied research to ensure the safe, reliable and economic operations of Australia's gas pipelines and networks, and its supporting infrastructure.
- Working closely with FFCRC to ensure a smooth transition
- Develop list of research topics/possible projects with **broad industry input**
- **Objectives include** use research to inform the development and **improvement of guidelines and standards** in the gas infrastructure industry
- Building now to replace Future Fuels CRC later in 2025.

Future research goals for renewable gases

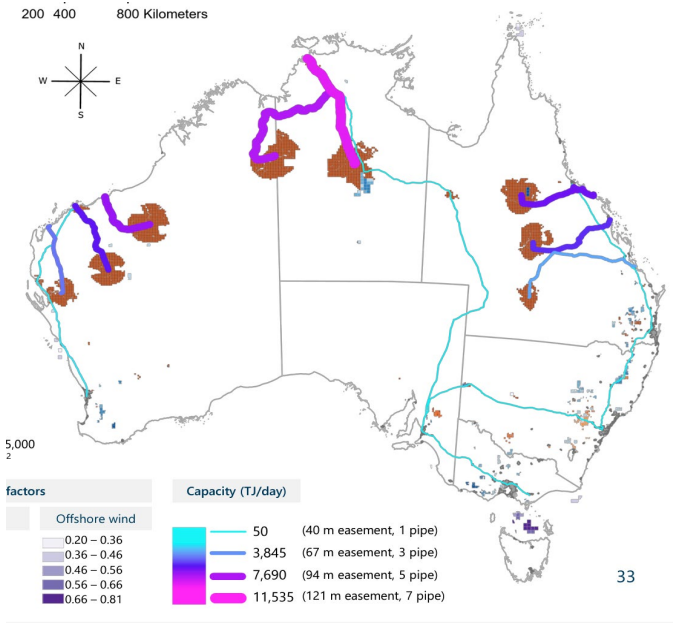
Underground energy storage



Whole-of-energy system modelling



ᵇ: Integrated system plan



Other research ideas

- RP2.3-08: Preparing for public safety assurance in the energy transition (plus other RP2 public safety research)
- RP3.4-01: Internal coatings for hydrogen service (Part 1 + 2)
- RP3.2-09 + RP1.4-07: Biomethane impurities (including O_2 and siloxanes)
- RP3.4-10: CO_2 pipeline impurities and internal corrosion

Can discuss further if there is interest….

Enabling the decarbonisation of Australia's energy networks

futurefuelscrc

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Future Fuels CRC is supported through the Australian Government's Cooperative Research Centres Program. We gratefully acknowledge the cash and in-kind support from all our research, government and industry participants.

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FFCRC Biomethane Research

RP1.2-03 Assessment framework for bio-methane injection in gas networks

This project undertook the co-development (i.e. with industry) of a generic framework for assessing the techno-economic viability of injecting bio-methane into existing gas networks in the Australian context and demonstrated its use for two case ...

RP1.2-04 Integrated model for bio-methane injection in gas networks

This project builds on the framework developed in RP1.2-03 and aims to develop and apply an integrated model for the techno-economic viability assessment of bio-methane projects in Australia. ...

RP1.2-06 Assessing the barriers to investability for bio-methane grid injection projects

Update February 2025: our latest webinar, assessment tool and Report 2: Identifying the most investable biomethane project sites in Australia are now available. ...

RP1.4-07 – Biomethane injection into the gas network: impact of impurities on the performance of end-use appliances

The overall objective of this project is to enable biomethane injection into the gas network in a cost-effective manner. The focus is on the end-user equipment and providing appropriate constraints on the level of impurities such as siloxane, oxygen ...

RP2.2-05 Policy pathways to advance Australia's biomethane sector: learning policy lessons from international jurisdictions

This project seeks to support the development of new biomethane markets and an associated biomethane industry in Australia. It will examine the policy mechanisms and initiatives that have been employed in a number of international jurisdictions with ...

RP3.2-09: Biomethane Impurities

This project aims to increase industry knowledge about biomethane contaminants and their interactions with existing pipeline impurities and end user equipment, to increase industry confidence in biomethane injection into gas transmission and ...

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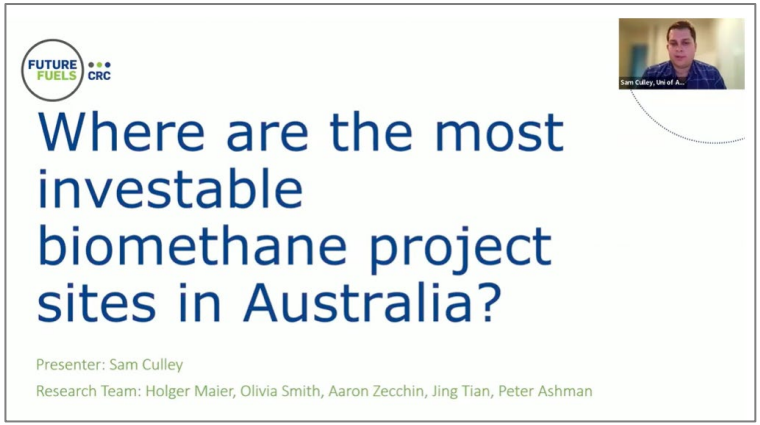
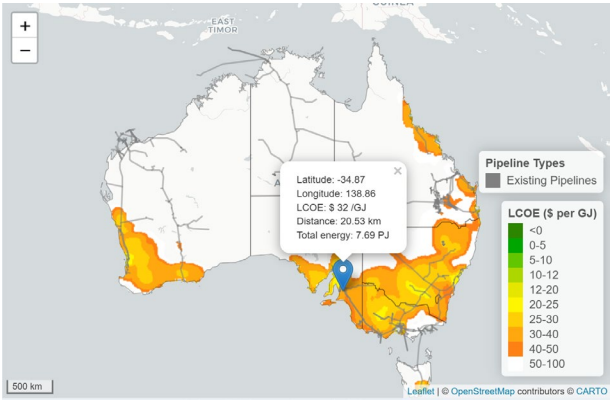
RP1.2 Biomethane Modelling

RP1.2-03, RP1.2-04 & RP1.2-06

- Three related projects which build on one another; focussed on systems modelling and viability assessment for biomethane projects
- Public webinar recently held for RP1.2-06 – assessment tool also available





Link to project web-page (incl. webinar + tool)

https://www.futurefuelscrc.com/project/rp1-2-06-assessing-the-barriers-to-investability-for-bio-methane-grid-injection-projects/

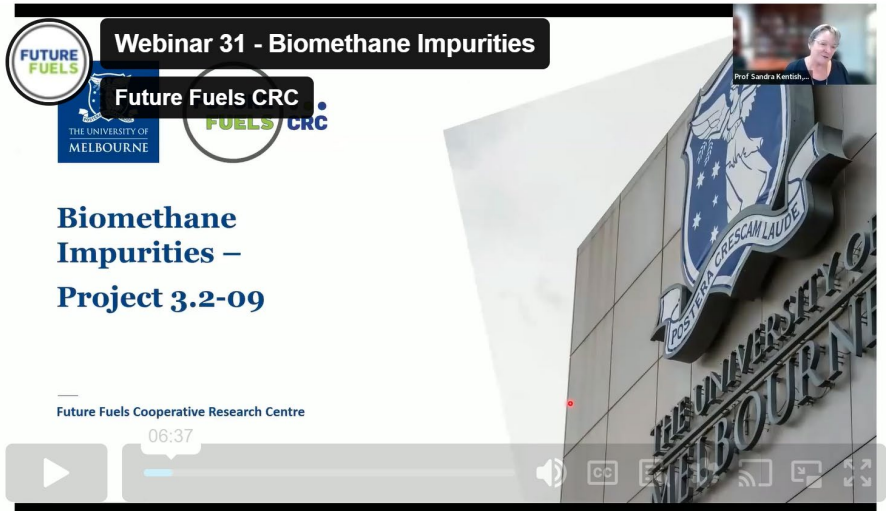
Biomethane Impurities Research

Impact on appliances (RP1.4-07) and pipelines (RP3.2-09)

- Viability of biomethane may depend on allowable impurities in some instances
- Focus is on O_2, N_2 and siloxanes
- End-use appliance research suggests that 7 vol% inerts limit in AS 4564 is appropriate
- Increasing allowable O_2 from current limit of 0.2 vol% is feasible for end-use devices
- Need to ensure that an increase in O_2 concentration does not lead to corrosion issues in pipelines → i.e. moisture content must be controlled
- Research also suggests a siloxane limit of up to 0.45 mg Si/m^3 (but may need more data)
- Outcomes have been discussed with AG-010 (recommendations for AS 4564)
- Results of RP3.2-09 have been made publicly available via website

Biomethane Impurities Research

Webinar held in October 2024 (Webinar #31)



https://www.futurefuelscrc.com/members-area/webinar-recordings/