FUTURE FUELS CRC

Enabling the decarbonisation of Australia's energy networks

Research Programs Update: November 2022

Research Program 1 Future Fuel Technologies, Systems and Markets

This program addresses the technical, economic and market challenges associated with the introduction of new low and zero carbon fuels.

The major research themes in this program include:

- Integrated planning of fuel systems production, delivery and use
- Techno-economic modelling of fuel production processes and supply chains
- Accelerated development of early stage, breakthrough technologies
- Compatibility of end user equipment with future fuels
- Applied research support of 'Power to Gas' demonstration projects

This program aims to deliver the following outcomes:

- New technology for the cost effective production of future fuels;
- Viable plans for the introduction of new fuels; reducing investment risk in new technology and infrastructure;
- Utilisation of gas networks to deliver decarbonised energy to consumers and providing more flexibility and reduced capital expenditure for electricity network stabilisation and storage;
- New domestic markets for reliable, cost effective low emission fuels and export opportunities in the Asia-Pacific region (where hydrogen transport fleets are being developed);
- Decarbonisation of the transport sector and industries that currently have limited options for emission reduction;
- Improved reliability of the electricity market by supporting cost-effective intermittent renewable generation with gas as an energy storage medium stored in existing infrastructure.

Overviews of approved research projects under this program are:

1.1 Integrated planning of fuel systems production, delivery and use

RP1.1-01: Scenario and broad-scale modelling dynamics

Using well-established scenario development processes and a range of economic and technical models (including CGE models), research was completed in mid-2021 that created the data sets and knowledge necessary to:

- Enable quantitative assessment of the socio-economic consequences of introducing hydrogen at both the regional and national level; and
- Identify the sectors and industries that may benefit most and/or be most challenged by the development of future fuel technologies and the resultant decarbonisation of the economy.

R&D Focus Areas: Computational modelling; Hydrogen market development; Policy
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 01/2019
RP1.1-01 Scenario and broad-scale modelling of future energy systems

RP1.1-02: Regional case studies on multi-energy system integration

The development of an energy systems model is underway to assist key energy market players in understanding the potential of different future fuel options to decarbonise the energy system. The research includes an assessment of integrated electricity-gas-hydrogen systems in the presence of different coupling technologies and scenarios for different sectors (e.g. injection of hydrogen into the gas network, production of low-carbon fuels for export, electrification vs decarbonisation of heating, etc.).

A state of the art integrated electricity-gas-hydrogen systems model was completed early 2021 to run several studies on behalf of industry. An example of such a study, which investigated the electrification of heating in Victoria can be found here.

R&D Focus Areas: Sector coupling; Energy systems integration; Techno-economic evaluation
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: In Progress
Start date: 03/2019
RP1.1-02 Regional case studies on gas and electricity system integration

RP1.1-02B: Regional case studies on multi-energy system integration

The imminent advent of large-scale green hydrogen production raises the central question of which of the two options, transporting green molecules, or transporting green electrons, is the most cost-effective one. This project aims to answer this question by determining the optimal integrated transmission and storage infrastructure solution for large-scale production of green hydrogen. Towards this aim, the work proposes an investment and operational assessment framework of integrated electricity-gas-hydrogen production, transmission, and storage technologies.

A summary of a related pipelines vs powerlines study can be found here.

R&D Focus Areas: Sector coupling; Energy systems integration; Techno-economic evaluation
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: In Progress
Start date: 07/2021
RP1.1-02B Transport and Storage Options for Future Fuels

RP1.1-03: Learning from international roadmaps and strategies

This project summarised 19 international hydrogen strategies and helped to understand how nations, regions and industries are thinking about opportunities to become involved in this emerging industry. It acts as an important resource to those involved in long-term energy policy planning in Australia.

A summary from this project can be found here.

R&D Focus Areas: Policy, Regulations
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 04/2019
RP1.1-03 Learning from international hydrogen roadmaps and strategies

RP1.1-04: Underground storage of hydrogen: mapping out the options for Australia

This project delivered a high-level assessment and mapping of the options for underground storage of hydrogen in Australia. This research provided the basis for more detailed local assessments of hydrogen storage to be carried out by government and industry (e.g. project RP1.2-05).

The final report has been made publicly available and can be downloaded here.

R&D Focus Areas: Underground storage
Lead Organisation: CSIRO
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2020
RP1.1-04 Underground storage of hydrogen: mapping out the options for Australia

RP1.1-05: FutureNet: Connecting and managing Renewable Gas projects across Australian gas networks

Gas networks are evolving from concentrated sources to distributed biomethane and hydrogen production across distribution networks and along transmission pipelines. To enable and prepare for this future industry must reset how the gas network is managed. Understanding the techno-economic aspects of distributed renewable gas injection into the network is an essential starting point, including identifying the requirements and potential for optimal capacity management to increase the level of renewable gas project connections. This project aims to identify the current best practices to enable at scale renewable gas injection into gas networks.

R&D Focus Areas: Computational modelling, Techno-economic evaluation, Pipeline and network operations
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In progress, literature review already available**
Start date: 10/2021
RP1.1-05 FutureNet: minimise the cost of connecting and managing renewable gas projects

RP1.1-06 – Net Zero Australia

With this project, Future Fuels CRC joins the Net Zero Australia (NZAu) consortium. The project will quantify the potential benefits, costs, and impacts of a future Australian economy that is built on clean, secure, and affordable energy services, and which makes efficient use of all Australia's energy resources.

R&D Focus Areas: Sector coupling; Energy systems integration, Computational modelling, Techno-economic evaluation
Lead Organisation: University of Melbourne, University of Queensland
Funding: Future Fuels CRC
Status: **In progress, interim report available at** https://www.netzeroaustralia.net.au/
Start date: 10/2021
RP1.1-06 – Net Zero Australia

RP1.10-01 Advanced power converter to improve fuel cell system performance

Develop, design and implement a more efficient conversion of power from the fuel cell to the power grid, investigate fuel cell interaction with fluctuations in the power system and how to improve its performance, investigate switching techniques in the power converter to reduce power loss.

R&D Focus Areas: Electricity (includes grid balancing & stability, grid integration, stationary fuel cells, engines & turbines)
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In progress
Start date: 02/2020
RP1.10-01 Advanced power converter to improve fuel cell system performance

RP1.10-02 Improving the efficiency of the renewable energy-based electrolyser

Investigate the areas of wind- and PV- based electrolysis integration, integration of power electronics, improvements in renewable energy conversion efficiency and energy transfer, and reduction of balance-of-plant capital costs to facilitate the integration of electrolysers in the development of new renewables into the electricity grids.

R&D Focus Areas: Electrolysis, Electricity (includes grid balancing & stability, grid integration, stationary fuel cells, engines & turbines)
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In progress
Start date: 02/2020
RP1.10-02 Improving the efficiency of the renewable energy-based electrolyser

RP1.10-03: Grid interaction of electrolyser and fuel cells for utilisation of renewable energy surplus
This project investigates: 1) Advanced power converter development to improve fuel cell system performance; 2) Improving the efficiency of the renewable energy-based electrolyser through power electronics optimisation; and 3) An advanced power flow controller for energy flow between the grid and electrolyser to produce hydrogen, and between fuel cell and grid to control the conversion of hydrogen to electricity.
R&D Focus Areas: Electrolysis, Technology integration process improvement
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2020
RP1.10-03 Grid interaction and electrolyser and fuel cells for use of renewable energy

1.2 Techno-economic modelling of fuel production processes and supply chains

RP1.2-01: Future fuels production - status review
A 'state-of-play' assessment of future fuels production technologies has been undertaken. This project has produced a report which summarises the current technology and commercial status of production technologies of future fuels.
R&D Focus Areas: Electrolysis, Fossil fuel conversion, Techno-economic evaluation
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP1.2-01 Future Fuels Production Technology – Status Review

RP1.2-02: Techno-economic modelling of fuel production processes
This project builds on RP1.2-01. It simulates all possible ways to produce hydrogen and biomethane. These simulations form the core technology and economic process information on which to base project decisions on the most prospective production processes and also integrate with and inform the energy systems modelling activity (RP1.1-02).
R&D Focus Areas: Electrolysis, Fossil fuel conversion, Techno-economic evaluation
Lead Organisation: University of Melbourne, University of Queensland, University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 01/2019
RP1.2-02 Techno-economic modelling of fuel production processes

RP1.2-03: Assessment framework for bio-methane injection in gas networks
This project successfully identified opportunities for the injection of bio-methane into existing gas networks and pipelines in Australia. This was done via the assessment of the techno-economic viability for two end-user defined case studies. Based on the case studies, a general framework for performing such assessments has been developed by identifying what factors need to be considered by bio-methane projects that want to connect to the gas network.
R&D Focus Areas: Computational modelling, Techno-economic evaluation, Market development
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 10/2019
RP1.2-03 Assessment framework for bio-methane injection in gas networks

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. The model would be robust and easy-to-use; and would benefit both industry end-users examining the viability of a potential site and policy makers exploring the effect of different incentives on the development of the bio-gas industry in Australia.
R&D Focus Areas: Computational modelling, Techno-economic evaluation, Market development
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 03/2021
RP1.2-04 Integrated model for bio-methane injection in gas networks

RP1.2-05: An integrated techno-economic and underground storage simulation tool
This study assesses the potential for underground hydrogen storage (UHS) from a systems perspective. Access to viable large-scale storage is a critical component of the hydrogen value chain and will have significant impacts when selecting a location. This work creates an integrated techno-economic and underground storage model for intermittent hydrogen production coupled with storage in a depleted gas reservoir to identify and quantify the limitations of this aspect on an Australia-based hydrogen value chain.
R&D Focus Areas: Techno-economic evaluation, Underground storage
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 10/2021
RP1.2-05 – An integrated techno-economic and underground storage simulation tool for intermittent hydrogen production coupled with a gas storage site

1.3 Accelerated development of early stage, breakthrough technologies

RP1.3-01: Solar photocatalytic hydrogen production
This project aims to develop technology that allows for the production of hydrogen with direct sunlight: a process known as photocatalysis. This process has potential cost advantages compared to other renewable hydrogen production technologies. The project focusses on new photocatalyst material development.
R&D Focus Areas: Photochemical and photocatalytic processes, Techno-economic evaluation
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, literature review available**
Start date: 11/2019
RP1.3-01 Solar Photocatalytic Hydrogen Production Technology Development

RP1.3-02: Novel H2/CH4 separation technology development
This project aims to develop novel technology for hydrogen separation in future fuels systems, also known as ‘deblending technology’. The technology to be developed in this project looks to change the concentration of hydrogen-methane mixtures and is highly relevant to industry. The adsorption-based separation technology allows for an increase in the range of equipment and appliances which can use a hydrogen-methane stream of variable concentration.
R&D Focus Areas: Separation materials and technologies
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 06/2019
RP1.3-02 Novel H2/CH4 Separation Technology Development

RP1.3-03: Methane pyrolysis for hydrogen production

The project aims to develop and demonstrate a novel process with strong potential to achieve a step-change in the cost of production of hydrogen from natural gas. Natural gas pyrolysis involves the cracking of methane into solid carbon and hydrogen, allowing the solid carbon to be sequestered, while also offering potential that some of the carbon may yield higher value by-products. The project focusses on both catalyst and reactor development.

R&D Focus Areas: Fossil fuel conversion, Separation materials and technologies
Lead Organisation: University of Queensland, University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 09/2019
RP1.3-03 Methane Pyrolysis for Hydrogen Production

RP1.3-04 Efficient conversion of hydrogen to methanol

This project aims to achieve efficient conversion of hydrogen to the alternative fuel methanol, through the development of hybrid membrane technology and bespoke catalysts for these conversions. The technology approach combines a catalytic reactor with membrane separation to achieve a membrane reactor, representing process intensification to reduce equipment footprint. This transformative technology assists hydrogen producers and CO_2 emitters to efficiently produce alternative fuels for their storage and transportation purposes.

R&D Focus Areas: Separation materials and technologies, Technology integration process improvement, Synthetic fuels and chemicals
Lead Organisation: University of Melbourne, University of Queensland, University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 01/2021
RP1.3-04 Efficient conversion of hydrogen to future fuels

RP1.10-06 Renewable hydrogen production by Reverse Electrodialysis

This project provides an analysis of the challenges and economic benefit of using reverse electrodialysis to capture the osmotic energy released when fresh water from rivers mixes with seawater. This energy can be captured as a mixture of renewable hydrogen and electricity. The main benefit of the project is a better understanding of the potential for this technology to generate hydrogen at a similar or lower price to that from solar electricity production, especially in areas where fresh and salt water streams come together.

R&D Focus Areas: Electrolysis, Electricity (includes grid balancing & stability, grid integration, stationary fuel cells, engines & turbines), Techno-economic evaluation
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2021
RP1.10-06 Renewable hydrogen production by reverse electrodialysis

RP1.10-07 Co-gasification of waste in a solar fluidized bed gasifier for hydrogen production

A key outcome of this project is the identification of the risks, challenges and economic benefits of using hybridised solar gasification for the production of hydrogen and hydrogen-based carriers from agricultural, wood processing and construction wastes. In addition to providing a technical and economical overview of using solar energy for conversion of waste biomass to valuable fuels, the conversion efficiency and performance of conventional, non-solar reactors will also be evaluated and compared.

R&D Focus Areas: Biomass and waste conversion, Techno-economic evaluation
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: In Progress
Start date: 01/2021
RP1.10-07 Biomass to future fuels – A techno-economic assessment

RP1.10-08 – Development of polymer-based wellbore completion material for underground hydrogen storage in depleted hydrocarbon reservoirs

This PhD research project aims to address one of the key issues of utilising existing underground gas storage (UGS) in depleted hydrocarbon reservoirs for underground hydrogen storage (UHS). The research project intends to develop a novel cement-liner combination based on polymers to be used in UHS application that can last for prolonged service period. This project provides solutions to address the wellbore integrity problems when utilising UGS facilities for UHS.

R&D Focus Areas: Underground storage
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: In Progress
Start date: 01/2022
RP1.10-08 – Development of polymer-based wellbore completion material for underground hydrogen storage

1.4 Compatibility of end user equipment with future fuels

RP1.4-01: Domestic gas appliance review and test program

This project (a) examined whether a wide range of common household appliances (Type-A) can operate safely on natural gas with a 10% hydrogen blend, (b) determined the maximum level of hydrogen that can be blended into natural gas before flash-back, ignition or other problems occur, and (c) identified potential technical appliance issues associated with natural gas blends that have higher levels of hydrogen than can be accommodated by current appliances. The results of the testing program are of particular interest to companies that are developing pilot projects that involve the injection of hydrogen into parts of the gas distribution system. A quick summary of the project can be viewed here.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP1.4-01 Future Fuels End-use – Type A appliances Test Program

RP1.4-01B – Room carbon monoxide levels in lit-under burner situations

This project provided quantitative information on the accumulation of carbon monoxide in domestic kitchens when cookers are operated in lit-back condition. This was achieved by experiments and modelling.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 10/2020
RP1.4-01B Room carbon monoxide levels in lit-under burner situations

RP1.4-01C - Light-under testing and CO modelling of cookers at 20% hydrogen blending levels
This short-term project builds on the research done in FFCRC projects RP1.4-01 and RP1.4-01B. It extends the work being done in project RP1.4-05 “Performance of Type A appliances with blends of hydrogen and natural gas”, by including more testing and modelling of cooker light-under CO emissions and concentrations inside rooms.
R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 5/2022
RP1.4-01C Light-under testing and CO modelling of cookers at 20% hydrogen blending levels

RP1.4-02: Future fuel use in Type B and industrial equipment
This scoping study identified the potential technical issues associated with converting Type B appliances (industrial burners, gas turbines and engines, and non-combustion methane users) to natural gas blends with higher levels of hydrogen than can be accommodated by current equipment.
The project summary can be downloaded here.
R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Industrial feedstock processes, Industrial heat processes
Lead Organisation: University of Adelaide, University of Melbourne
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 06/2019
RP1.4-02 Future fuels End-use – Type B appliances and Industrial equipment

RP1.4-03 Pathways for hydrogen adaptation to industrial processes
This project de-risks the adaptation of hydrogen to some Type-B appliances which are key to industrial processes, in particular cement and alumina production, through a combined experimental and computational research program at scale. It quantifies the impact of hydrogen blending on the characteristics of the resulting flames including size, stability, heat transfer and emission. The results inform gas suppliers and industrial users of the limits, potential impediments and opportunities of hydrogen blending.
R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Industrial heat processes, Industrial feedstock processes
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 05/2020
RP1.4-03 Pathways for hydrogen adaptation to industrial processes

RP1.4-04 Hydrogen gas specification and review of end-user instrumentation
This project developed specifications for hydrogen to be used in Australia. It also included a review and assessment of the impacts of adding hydrogen to natural gas, or using 100% hydrogen, on instrumentation used by industrial and commercial end users. The review gathered information from suppliers, industry experts and literature on the influence of hydrogen on end-user instrumentation and safety equipment.
R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards, Specialised components and devices
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2020
RP1.4-04 Hydrogen gas specification and review of end-user instrumentation

RP1.4-05 Performance of Type-A appliances with blends of hydrogen and natural gas

This project builds on the research done in RP1.4-01 and RP1.4-01B and aims to defining a practical upper limit for hydrogen addition to natural gas for operation of domestic gas appliances. An upper hydrogen percentage limit in blends with natural gas based on minimal changes to appliances will be indicated. As part of this project a range of new and legacy appliances will be tested, including cookers and flueless heater systems. The project will also test 100% hydrogen burners in terms of their ability to operate safely on hydrogen / natural gas mixtures.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 02/2021
RP1.4-05 Performance of Type A appliances with blends of hydrogen and natural gas

RP1.4-06 Assessment of Type B appliances with blends of hydrogen and natural gas

This project arose because of the complexity of defining what are the most important things to consider and what are the most relevant tests to conduct when assessing compatibility of commercial and industrial (Type-B) appliances with hydrogen / natural gas blends. Its purpose was to inform future projects by undertaking a desktop review and delivering a detailed test plan. The test plan is based on assessment of many (but not all) varieties of Type B appliances in Australia and in network-blending project regions.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards, Industrial heat processes (includes steel, cement, metals refining, etc)
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2021
RP1.4-06 Planning detailed assessment of Type B appliances with blends of hydrogen and natural gas

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 and nitrogen. This project investigates the impact of impurities on the end-users using state-of-the-art computational and experimental approaches.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 10/2021
RP1.4-07 – Biomethane injection into the gas network: impact of impurities on the performance of end-use appliances

RP1.4-08: Detailed assessment and testing of commercial appliances with hydrogen

There is a strong industry need to cost-effectively identify any compatibility issues of commercial and (light) industrial appliances and burners with hydrogen. Based on the test plan developed in RP1.4-06, in this project experiments are being performed on compatibility of commercial burners, appliances, and ancillary equipment with 10 mol% hydrogen in natural gas (allowing variation up to 21.7%) and maximum hydrogen percentages without changes and with minor changes. It will also test a limited number of retrofits for 100% hydrogen, especially those that are likely to be cost effective. Predictive models and costing tools are being developed for comparing retrofits with new hydrogen or electric appliances.

R&D Focus Areas: Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation), Safety and standards, Industrial heat processes (includes steel, cement, metals refining, etc)
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 10/2021
RP1.4-08 – Detailed assessment of Type B appliances with blends of hydrogen and natural gas and 100% hydrogen

RP1.10-04 Effects of dopants on hydrogen flames

This project assesses the feasibility of doping hydrogen with higher-order hydrocarbons and their effectiveness on visibility, radiation and odour.

R&D Focus Areas: Emissions and atmospheric impacts, Safety and standards, Gas networks and appliances
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2020
RP1.10-04 Effects of dopants on hydrogen flames

RP1.10-05: Impact of hydrogen addition on the performance of premixed gas turbines, reciprocating engines and industrial burners

This project aims to understand how pressure impacts the burning of hydrogen / natural gas mixtures under conditions relevant to gas turbines, reciprocating engines and industrial burners. It considers what physical limits in terms of engines performance and flame stability there are to hydrogen addition and how these might be addressed.

R&D Focus Areas: Industrial heat processes, Safety and standards, Gas networks and appliances (includes appliance testing, metering, hydrogen gas separation)
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2020
RP1.10-05 Impact of hydrogen on performance of gas turbines, industrial burners

Research Program 2 Social Acceptance, Public Safety and Security of Supply

This program is undertaking research into social and policy and regulatory contexts, including public acceptance and safety, within which future fuels infrastructure operates.
The major research themes in this program include:

- Appropriate community engagement to enable change
- Policy and regulatory solutions for new technology governance
- Organisational accident prevention
- Urban encroachment and infrastructure damage prevention

This program aims to deliver the following outcomes:

- Social licence for the adoption and use of future fuels by industry users and the community;
- A neutral, trustworthy source of future fuels information established to allow the industry to move forward;
- Continued world's best practice safety and reliability performance of Australian fuel transmission, distribution and storage infrastructure, through policy, regulation and industry practice;

- Reduced risk of major incidents associated with operation of existing and future fuel infrastructure;
- Optimal outcomes for companies, governments and society in the development and refitting of large energy projects and infrastructure;
- Sound policy to support governance of new fuel technology, infrastructure use to enable successful adoption, implementation and management;
- Effective regulation to enable the safe introduction of new low carbon fuels.

Overviews of approved research projects under this program follow.

2.1 Appropriate community engagement

RP2.1-01: Lessons Learned from major infrastructure upgrades
This project documented lessons learnt from earlier major upgrades to national energy infrastructure and identified effective engagement strategies that can be used in the potential conversion of gas networks to operate with hydrogen and / or other zero carbon gases. Case studies addressed include the transformation from 'town gas' to natural gas and the introduction of ethanol (E10) into the gasoline market.
The final report resulting from this project can be downloaded here.
R&D Focus Areas: Social licence, communication and engagement
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 04/2019
RP2.1-01 Lessons Learned from major infrastructure upgrades

RP2.1-02: A social licence and acceptance of future fuels
The project aims to develop an understanding of various stakeholder attitudes towards future fuels and monitoring changes in attitudes of those stakeholders (e.g. affected local communities, trades and associated workers and emergency service workers and the broader public). A key deliverable is the development of a range of trustworthy information tools for project proponents and policy makers to assist in the safe introduction and use of future fuels.
The results of a national public survey on attitudes towards hydrogen can be downloaded here.
R&D Focus Areas: Social licence, communication and engagement
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 07/2019
RP2.1-02 A social license and acceptance of future fuels

RP2.1-03: Mapping key stakeholders in Australia's energy transition
This project mapped key industry, government and civil society stakeholders currently engaged in the dialogue about Australia's energy transition and provides an overview of key messages. Furthermore, it catalogued the range of white papers, reports and websites generated by each stakeholder group.
R&D Focus Areas: Communication and engagement
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 12/2019
RP2.1-03 Mapping key stakeholders in Australia's energy transition

RP2.1-04: Developing appropriate protocols for naming future fuels
This project involved a systematic collection of actual and proposed names for current and future fuels. The project team reviewed Australian regulation on product naming conventions to crystallise any limits which might exist or emerge towards naming singular and blended products for domestic use and commercial export.
R&D Focus Areas: Hydrogen certification schemes, regulation
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP2.1-04 Developing appropriate protocols for naming energy future fuels

RP2.1-05: Public communication and hydrogen as a fuel in Australia
As communication is key to linking people and technologies, as well as stakeholders to each other, research has been completed to understand how people engage and communicate on the topic of future fuels across public events.
R&D Focus Areas: Communication and engagement
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2020
RP2.1-05 Public Communication and Hydrogen as a Fuel in Australia

RP2.1-06 Mapping vulnerability to future fuels – A scoping review
This project addressed the issue of energy vulnerability and disadvantage within the context of residential energy services. At the start of this project, the impact of new fuels on vulnerable customers is unknown. New knowledge has therefore been created to support customer engagement, innovation and adoption of future energy services.
R&D Focus Areas: Social-technical risks, Social licence
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 05/2020
RP2.1-06 Mapping vulnerability to Future Fuels – A Scoping Review

RP2.1-07 Deliberative engagement processes on the role of future fuels in the future low-carbon energy mix in Australia
This project aims to hold three deliberative engagement processes in three different Australian capital cities to investigate the role of future fuels in the future low-carbon energy mix in Australia. By hosting three deliberative panels this project aims to: 1) outline challenges, opportunities and priority actions that will help Australia to deliver the full potential of a low-carbon energy future; and 2) identify issues, benefits, drawbacks and trade-offs related to the implementation of future fuels in the future energy mix.
Three online citizens' panels have now been completed and the associated reports have been made publicly available. Please click here to access these reports.
R&D Focus Areas: Social licence, communication and engagement.
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 08/2020
RP2.1-07 Deliberative engagement processes on the role of future fuels in the future low-carbon energy mix in Australia

RP2.1-09 Social licence to operate training package

This project has led to an education and training package directed at practitioners working across industry, government and academia. The package has two goals. The first is to build an understanding of the concept of Social License to Operate (SLO). Secondly, it outlines and develops the skills required to proactively manage SLO as it applies to future fuels.

The training guide can be downloaded here. Please contact us for further information.

R&D Focus Areas: Social licence
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 04/2020
RP2.1-09 Social licence to operate training package

RP2.1-10 Understanding householder electricity and gas practices – Managing the transition of vulnerable customers towards future fuels

Responding to the industry need to better understand how people use and trade off gas and electricity in their homes, this mixed methods study will explain householder energy consumption patterns and practices, how they feel about and respond to different energy sources and how these are shaped by, or shape, vulnerability and affordability. This knowledge of both the cost and non-cost drivers of energy use is needed to help better manage the transition to future fuels or all electric homes.

R&D Focus Areas: Social licence, socio-technical risks
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: In progress
Start date: 02/2022
RP2.1-10 Understanding householder electricity and gas practices

RP2.1-11 An international comparison of media representations of (natural) gas and hydrogen – Framing issue legitimacy

This study is examining how gas is represented in international, national and social media. With an extensive analysis of media and strategic communication and various visualization strategies, the project identifies the gaps in existing corporate storytelling with focus on hydrogen and renewable gas.

R&D Focus Areas: Social licence, socio-technical risks
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: In progress
Start date: 02/2022
RP2.1-11 An international comparison of media representations of (natural) gas and hydrogen

RP2.10-01 Decision making and the role of social licence in natural resources

This project explored the relationship between social licence, decision making and economics. Specifically, the research sought to understand the motivations behind social licence concern and tested extended theoretical understanding about community and stakeholder social licence decision-making using the future fuels industry as a case study.

R&D Focus Areas: Social licence
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 12/2019
RP2.10-01 Decision making and the role of social licence in natural resources

RP2.10-02 Fostering social acceptance of future fuels in Australia

The project explores community responses, resistance to and social acceptance of a range of fuels. The accuracy and efficacy of relevant communication strategies (by government, commercial and civil society) is a key aspect of this project, as any social licence to operate may be influenced by a wide range of 'truths', perceived environmental risks and trade-offs. Understanding the critical dynamic between information, communication, and community and social acceptance of future fuels is an important research matter.

R&D Focus Areas: Social licence, communication and engagement
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: In Progress
Start date: 11/2020
RP2.10-02 Fostering social acceptance of future fuels in Australia

2.2 Policy and regulatory solutions for new technology governance

RP2.2-01: Regulatory mapping of future fuels

This project has undertaken a regulatory mapping exercise to identify where gas composition (or other gas properties) are mentioned or implied in relevant acts and regulations. Australia's gas infrastructure is subject to a range of regulations that are all designed for facilities that use natural gas. It identified regulatory changes required to ensure that future fuels can be used appropriately, and that regulation remains consistent with public policy objectives.

The full report and regulatory database can be downloaded here.

R&D Focus Areas: Regulations, Safety and standards
Lead Organisation: RMIT University, University of Sydney, GPA Engineering
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP2.2-01 Regulatory mapping for future fuels

RP2.2-03 Identifying drivers of policy and practices regarding future gas uses in the built environment

This project informs the renewable gas and hydrogen sector about current changes to building and planning policy and practice regarding the inclusion of gas in the built environment and who is driving the current changes. This allows the gas sector to more effectively engage relevant stakeholders to ensure that the interests of (renewable) gas consumers are considered in Australia's domestic residential energy future.

R&D Focus Areas: Policy, regulations, socio-technical risks
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2021
RP2.2-03 Identifying drivers of policy and practices regarding future gas uses in the built environment

RP2.2-04 Understanding the implications of a Renewable Gas Target for Australia's gas networks

This project is designed to allow stakeholders to better assess the implications of policy options for a national Renewable Gas Target (RGT) and their implications for the broader adoption of future fuels. It considers alternative approaches to the design and implementation of a national RGT, their implications for Australia's future fuels mix and their implications for economic outcomes in the Australian States and Territories.

R&D Focus Areas: Policy, regulations, socio-technical risks
Lead Organisation: University of Adelaide
Funding: Future Fuels CRC
Status: **In progress, webinar available**
Start date: 04/2022
RP2.2-04 Understanding the implications of a Renewable Gas Target for Australia's gas networks

2.3 Organisational accident prevention

RP2.3-02: Code of practice for pipeline engineers
Work has been completed to draft a new 'code of practice' for pipeline engineers under the guidance of an industry steering committee. It will raises awareness and understanding of organisational causes of accidents and how everyday engineering work has a direct impact on public safety outcomes.
The Public Safety in the Pipeline Industry: An Engineering Practice Guide was launched by the APGA in February 2022. Please click here to access it.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2019
RP2.3-02 Code of Practice for pipeline engineers

RP2.3-03 Establishing a case-based learning framework for pipeline engineers
The project produced a set of case-based learning experiences for professional pipeline engineers based on past incidents with specific resonance for the challenges of public safety and security of supply in a future fuels environment. The ultimate aim of this work is to maintain and promote excellence in engineering professional practice.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University, University of Canberra
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2020
RP2.3-03 Establishing a Case Based Learning Framework for Pipeline Engineers

RP2.3-04 Gas fitting practices for future fuels: Opportunities for training and upskilling in Victoria and South Australia
Gas fitting is a specialist licensed trade that requires training, accreditation and registration. Despite the differences in certification and professional development that exist across the Commonwealth, ensuring capacity and skills is in the national interest. This project uses Victoria and South Australia as detailed case studies to assess changes in resourcing and education in the gas fitting trade that are required to support the transition to, and ongoing maintenance of, a low-carbon economy.
R&D Focus Areas: Skills and labour market
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **In Progress, reports available**
Start date: 11/2020
RP2.3-04 Gas fitting practices for future fuels: Opportunities for training and upskilling in Victoria and South Australia.

RP2.3-05 ALARP Decision Making
The pipeline sector puts significant effort in to managing the potential for high consequence, low frequency accidents. For transmission pipelines, the framework for these activities is set out in AS/NZS 2885 Part 6 Pipeline Safety Management. New requirements were developed in 2014 to 2018 and included in the current version of the standard issued in 2018. The scope of this research project is to investigate the experience of industry in implementing these requirements, in particular a formal demonstration that risk is as low as reasonably practicable (ALARP), with a view to determining how safety decision making could be further improved, particularly in the context of future fuels.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 12/2020
RP2.3-05 ALARP decision making

RP2.3-06 Risk governance for procurement in Future Fuels
For the speedy development of a future fuels sector in Australia, it is important that early projects are successfully executed. A key issue for all major infrastructure projects is successful supply chain management. This research project aims to support risk management in procurement in the context of future fuels.
R&D Focus Areas: Safety and standards, Supply chain integration
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **In Progress, reports available**
Start date: 05/2021
RP2.3-06 Risk Governance for Procurement in Future Fuels

RP2.3-07 Development, delivery and evaluation of public safety workshops and a serious game/simulation for engineers
The project builds on the learning framework developed under project RP2.3-03 to develop, deliver and evaluate two different types of professional learning experiences regarding system safety in future fuels. The two modes are face to face workshops exploring lessons from accident cases and a workshop simulating project decision making incorporating a serious game.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: In Progress
Start date: 08/2022
RP2-3-07 public safety workshops and a serious game

2.4 Urban encroachment and infrastructure damage prevention

RP2.4-01: Pipeline intrusion avoidance solutions
Above ground drilling and excavation are one of the main causes of failure of underground gas pipelines and networks. The goal of this project is to advance understanding of the effectiveness of intrusion avoidance solutions, including one-call systems, and to provide industry with tools and recommendations on how they can systematically evaluate solutions.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 12/2019
RP2.4-01 Pipeline intrusion avoidance solutions

RP2.4-02: Understanding drivers for damage to distribution assets
Industry expends significant resources in mitigating the potential for third party damage to buried distribution assets. While most of this infrastructure operates at quite low pressure, the potential for injury and property damage remains. Increasing digitalisation means that records are now available on the details of damage to distribution assets. This research project will collate this data and use it for trend analysis to characterise damage to distribution assets in Australia with a view to developing new strategies for risk reduction.
R&D Focus Areas: Safety and standards
Lead Organisation: RMIT University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 12/2020
RP2.4-02 Damage to distribution assets

Research Program 3 Network Lifecycle Management

This program is undertaking novel materials, design, construction and operations-related research to enhance the operations of infrastructure carrying existing and future fuels.
The major research themes in this program include:

- Material properties and performance
- Safe and efficient design, construction and operation of future fuel infrastructure
- Smart monitoring, data management and asset condition prediction
- Advanced infrastructure repair and protection systems

This program aims to deliver the following outcomes:

- Effective design standards and operating procedures for transport and storage of future fuels in new and existing pipeline systems;
- Opportunities to extend the life of existing infrastructure through repurposing existing networks and facilities to support the transportation of new low carbon fuels;
- New materials for effective and safe transport and storage of future fuels;
- Reduced capital costs of new energy transportation infrastructure, and reduced operating and maintenance cost of infrastructure;
- More accurate, real-time assessment of the condition of metallic and plastic pipes through cost-effective sensing technology for detection, monitoring and evaluation of pipe degradation;
- Enhanced asset management decision-making through tools using advanced detection technologies, data analytics and service life-time prediction models covering a wide range of fuels and materials.

Overviews of approved research projects under this program follow.

3.1 Material properties and performance

Steel materials

RP3.1-01: Review of future fuels transport and storage technologies

This project included a review of industry standards, past and on-going RD&D projects regarding the compatibility of future fuels with metallic components of both pipeline transmission and distribution networks. The project assists researchers and industry to identify typical scenarios relevant to “Australian conditions” for using existing natural gas pipelines to transport hydrogen-natural gas blends.
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP3.1-01 Review of future fuels transport and storage technologies

RP3.1-02: Atom Probe tomography for hydrogen-steel interactions

The objective of this research is to gain better understanding of the interactions between metals in the existing gas pipeline network and hydrogen. High strength steels are known to be particularly sensitive to hydrogen embrittlement, which manifests as a reduction in mechanical properties and increased susceptibility to failure. Examining where and how the hydrogen interacts with the microstructure using Atom Probe Tomography (APT) is important to improve understanding of the impact of hydrogen on mechanical performance.
R&D Focus Areas: Pipeline materials and performance, Hydrogen embrittlement
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 09/2019
RP3.1-02 Atom Probe Tomography for hydrogen interactions with steel pipes

RP3.1-06: Study of hydrogen permeation through the pipe wall
This project seeks to answer an important consideration for the development of a fracture control plan for pipelines transporting hydrogen: “How much hydrogen is impregnated into the pipe-wall when hydrogen is pressurised internally?” To answer this, a test system is being deployed to evaluate the level of hydrogen concentration absorbed in pipe materials. Outcomes of the project provide immediate knowledge to industry on the impact of hydrogen on the existing infrastructure and how hydrogen changes the current structural integrity assessment models.
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 07/2019
RP3.1-06 Hydrogen permeation through the pipe wall

RP3.1-08: Full-scale fracture initiation test programme – Phase 1: Project execution plan
This project is the first phase of a full-scale fracture initiation test program. Full-scale testing of fracture initiation in hydrogen service will be an essential contribution to determining the safe operating window for high-pressure steel pipelines in hydrogen service. This project reviewed options for conducting full-scale initiation tests, and provide a project execution plan for subsequent project phase(s).
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 05/2020
RP3.1-08 Full-scale fracture initiation test programme –Phase 1: Project execution plan

RP3.1-09: Deployment of the SAFE(TI) Lab for characterising the mechanical properties of line-pipe steels exposed to high-pressure gaseous H2
This project establishes a state-of-the-art testing laboratory to characterise line-pipe steels exposed to high-pressure, gaseous hydrogen. The laboratory is named the SAFE(TI) Lab – an acronym for the Structural Assessment of Future Energy Transport Infrastructure. The laboratory centralises testing ranging from permeation testing, to high-strain rate testing, to fatigue testing of line-pipe steels intended for the transmission network. The laboratory allows for researchers and industry to explore the limits of existing pipeline networks for their maximum potential to transport pressured hydrogen/methane blends.
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 09/2020
RP3.1-09 Deployment of the SAFE(TI) Lab for characterising the mechanical properties of linepipe steels

RP3.1-09B: Purchase of two new Hydrogen Universal Testing Machines
The H2SAFE(TI) Lab funded by the Future Fuels CRC (RP3.1-09) is used to conduct mechanical testing on representative Australian pipeline samples to quantify the effects of hydrogen embrittlement and its implications for fracture control paradigms. This project expands the capabilities of the H2SAFE(TI) Lab through the purchase of two new Hydrogen Universal Testing Machines. This provides more capacity to test steels for the Australian pipeline industry seeking to introduce hydrogen into their transmission networks.
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **Complete**
Start date: 09/2020
RP3.1-09 Deployment of the SAFE(TI) Lab for characterising the mechanical properties of linepipe steels

RP3.1-10: Hydrogen embrittlement of pipeline steels, subcritical crack growth (formation) and critical crack growth (initiation)

The research aims to elucidate the hydrogen embrittlement (HE) manifestations of gas pipeline steels based on recent research which has shown that the influence of hydrogen (for a large range of equivalent hydrogen pressures up to 2,000 bar) on steels can be determined by the use electrolytic (cathodic) hydrogen charging combined with mechanical testing. The proposed research addresses knowledge gaps identified in the "Future Fuels CRC Hydrogen in Pipelines Research Roadmap" focussing on sub-critical crack growth (formation) and critical crack growth (initiation).

R&D Focus Areas: Pipeline materials and performance, Hydrogen Embrittlement
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 08/2020
RP3.1-10 Hydrogen embrittlement of pipeline steels, subcritical and critical crack growth

RP3.1-11: Thermic Welded Electrical Conductor to Gas Pipelines

This project carries out a literature and industry survey to determine the state of the art for the use of aluminothermic welding to safely and effectively to weld electrical conductors to live gas pipelines to facilitate cathodic protection as well as electrical earthing of lightning strikes. Currently limits to aluminothermic welding for cable connections are applied in Australian standards. The requirements of AS 2885 and AS 3000 add project costs that may be unnecessary. Alternative methods will be investigated.

R&D Focus Areas: Pipeline design and integrity management, Safety and standards
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: **Complete, research reports available**
Start date: 07/2021
RP3.1-11 Thermite Welded Electrical Conductor to Gas Pipeline – Literature

RP3.1-12: Characterising representative Australian transmission pipelines in high-pressure hydrogen

The project addresses several industry needs regarding the testing of pipeline materials in a hydrogen environment to characterise the change in material properties. This information is used to create a material database of Australian pipeline material performance in hydrogen service, which allows for the development of new design equations and predictive models. In addition, the project provides a hydrogen testing lab capable of characterising material performance and meet the testing demand currently required by the industry.

R&D Focus Areas: Pipeline materials and performance, Pipeline design and integrity management, Safety and standards, Hydrogen Embrittlement
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In progress
Start date: 04/2022
RP3.1-12: Characterising representative Australian transmission pipelines in high-pressure hydrogen

RP3.1-13: Feasibility of the use of gas phase inhibition of hydrogen embrittlement in gas transmission pipelines carrying hydrogen

This research will provide critical knowledge regarding the inhibition of hydrogen embrittlement (HE) by small amounts of added gases (O2, CH4, CO, CO2). If 100% inhibition of HE were practical, then the mechanical behaviour of the pipeline steel for a hydrogen carrying pipeline would be exactly the same as that of a gas transmission pipeline with no hydrogen and the operating characteristics would remain the same as at the present time, regardless of the hydrogen content of the gas inside the gas transmission pipeline.

R&D Focus Areas: Hydrogen Embrittlement, Pipeline materials and performance
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2022
RP3.1-13: Feasibility of the use of gas phase inhibition of hydrogen embrittlement in gas transmission pipelines carrying hydrogen

RP3.10-01: Molecular dynamics investigations of hydrogen-induced plastic deformation and failure
This PhD research conducts molecular dynamics modelling studies on the effect of hydrogen on grain boundary activities for various material.
R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 10/2020
RP3.10-01 Molecular dynamics investigations of hydrogen-induced plastic deformation and failure

RP3.10-02: Hydrogen and pipeline steels: orientation dependence of fracture toughness
The worst-case influence on the fracture toughness caused by the orientation of the crack is being studied in RP3.1-10 'Hydrogen embrittlement of pipeline steels, subcritical crack growth and critical crack growth'. This project complements the RP3.1-10 by analysing the fracture toughness in two other crack orientations as well.
R&D Focus Areas: Pipeline materials and performance, Hydrogen embrittlement
Lead Organisation: University of Queensland
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2022
RP3.10-02: Hydrogen and pipeline steels: orientation dependence of fracture toughness

RP3.10-03: Development of a ductile damage-based fracture initiation model for natural gas and hydrogen transmission pipelines
This industry PhD project aims to develop a validated ductile damage model for prediction of fracture initiation and defect assessment in natural gas and hydrogen pipelines.
R&D Focus Areas: Pipeline materials and performance, Pipeline design and integrity management
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 01/2022
RP3.10-03: A ductile damage-based fracture initiation model for natural gas and hydrogen pipelines

Plastic and composite materials

RP3.1-03: Future proofing plastic pipes
This project has started development of a standardised suite of tests to identify polymer/elastomeric compatibility with hydrogen and its blends and generates an understanding of the capacity for current pipeline materials (plastics and elastomeric) to transport future fuels.
R&D Focus Areas: Pipeline and network operations, Pipeline materials and performance, Safety and standards
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 02/2019
RP3.1-03 Future proofing plastic pipes

RP3.1-04: Multi-channel hydrostatic pressure test kit
Hydrostatic pressure testing is a method to assess the performance of various types and grades of plastic pipes. This method has been standardised under ASTM D1598-2004 and ISO1667-2006 to evaluate industry-wide pipeline performance. The test equipment has been incorporated into existing and future research projects, including RP3.1-03.
R&D Focus Areas: Pipeline materials and performance, Safety and Standards
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP3.1-04 Multi-channel hydrostatic pressure test kit

RP3.1-05: Compatibility of plastic piping with future fuels

This project focuses on the compatibility of plastic piping systems with future fuels other than hydrogen, including biogas, methanol, syngas, etc. The compatibility is being evaluated by quantifying structural change to the various plastic materials (e.g. polyethylene, nylon), including swelling, tensile strength change, delamination, as well as determining if the fuels permeate through the materials.

R&D Focus Areas: Pipeline and network operations, Pipeline materials and performance
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 07/2019
RP3.1-05 Compatibility of plastic piping with future fuels

RP3.1-07: Hydrogen test bed - plastic pipe network

This project implements a dedicated hydrogen field test bed to enable long-term compatibility of typical gas distribution network components to be evaluated. A specific focus of this project is to evaluate the impact of hydrogen on the performance of junctions and welds which are currently used by the industry.

A video of the testbed under construction can be downloaded here.

R&D Focus Areas: Pipeline and network operations, Pipeline materials and performance, Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 03/2020
RP3.1-07 Hydrogen test bed – plastic pipe network

3.2 Safe and efficient design, construction and operation of future fuel infrastructure

RP3.2-01: Proximity and ventilation requirements for distribution networks adapted to future fuels

This project aims to undertake experimental, analytical and numerical studies to provide clear guidance on ventilation requirements in enclosed gas metering stations and the safe proximity distances between gas mains and buildings for gas distribution networks in Australia. These guidelines are particularly relevant for situations where the fuel is changing from natural gas towards hydrogen.

R&D Focus Areas: Pipeline and network operations, Safety and standards
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 07/2019
RP3.2-01 Proximity and ventilation requirements for fuel networks

RP3.2-02: Future fuels decompression behaviour

The control of running ductile fracture in high pressure transmission pipelines is supported by models, experiments and regulatory standards. Transportation of future fuels in pipeline systems raises questions on the applicability of the prediction methods used by these existing models (developed for natural gas). This research project places particular focus on the decompression characteristics of hydrogen-methane mixture compositions. As the major contributing factor of the driving force to propagate the fracture, the decompression of the mixture needs to be predicted with high accuracy.

R&D Focus Areas: Pipeline materials and performance
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 08/2019
RP3.2-02 Assessment of future fuel decompression behaviour

RP3.2-03: The AS2885 online community

The Australian Standard "AS2885" is widely seen as a go-to document for pipeline engineers to design, construct, and operate a safe pipeline. This project developed an online AS2885 handbook / community: https://as2885.info/ It provides a series of documents, discussions and references to help users resolve the technical and application uncertainties that accompany a Standard like AS 2885. The platform will be used throughout the life of the CRC for future discussion around the design and operation of, for example, hydrogen pipelines.

R&D Focus Areas: Safety and Standards
Lead Organisation: Australian Gas and Pipeline Association (APGA)
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2019
RP3.2-03 The online AS 2885 handbook

RP3.2-04: Cohesive gas impurities

Electrically conductive deposits are observed in some pipelines carrying coal seam gas that are impacting cathodic protection (CP) operation and fouling equipment. This project confirmed that the nature of the deposits and developed potential solutions to reduce their extent and/or impact. The results of this work are relevant to both existing and future gaseous fuels.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date:12/2019
RP3.2-04 Cohesive Gas Impurities

RP3.2-04B: Cohesive Gas Impurities – Phase 2

Research undertaken in RP3.2-04 concluded that the introduction of consistent, low levels of liquid triethylene glycol contamination associated with the dehydration process of natural gas contributed to substantial negative impacts on the operation of pipeline corrosion protection systems. This project continues this research by producing experimental data to support the inclusion of design guidelines into Australian Pipeline Standard AS2885.

R&D Focus Areas: Pipeline design and integrity management, Safety and standards
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 11/2020
RP3.2-04B Cohesive Gas Impurities – Phase 2

RP3.2-05: Tensile strain capacity (projects A, B and C)

This project provides a better understanding on tensile strain capacity, and specifically tensile strain capacity under various weld strength matching conditions (over and under matching). This will enable designers and project proponents to optimise designs for new pipelines. It will also allow for assessment of existing pipelines in the vicinity of girth welds under weld strength (under/over) matching conditions.

R&D Focus Areas: Pipeline materials and performance, Materials modelling
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **In Progress, interim reports and literature review available**
Start date: 12/2019
RP3.2-05A Pipeline Tensile strain capacity – Project 1 Literature review
RP3.2-05B Pipeline Tensile strain capacity – Project 2 Experimental evaluation
RP3.2-05C Pipeline Tensile strain capacity – Project 3 Predictive Tool

RP3.2-06: Development of a new fracture propagation model based on advanced damage models accounting for the effects of stress-state on failure

This project focusses on the development of a new model capturing accurately the physics at play during a running ductile fracture event in a pipeline. This fracture control model is based on an alternative representation of the material's resistance to fracture, and can be applied to different fluids, for example natural gas, hydrogen and carbon dioxide.

R&D Focus Areas: Pipeline materials and performance, Materials modelling
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date: 02/2020
RP3.2-06 Development of a New Fracture Propagation Model

RP3.2-07: Metering and gas quality monitoring of future fuel blends in transmission pipelines

This project defined the measurement uncertainty levels of commonly used measurement instrumentation when deployed on hydrogen-natural gas blends and assess the performance of flow computing and other gas measurement software systems when future fuel blends are introduced.

R&D Focus Areas: Pipeline design and integrity management, Pipeline and network operations, Specialised components and devices
Lead Organisation: University of Adelaide, University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 03/2020
RP3.2-07 Metering and gas quality monitoring of future fuel blends

RP3.2-08: Development of efficient and effective methodologies for the abandonment of pipelines

This project delivered technical guidelines for end-of-life pipeline decommissioning and abandonment, based on international practices translated for Australian situations. This research supports decision making around abandonment vs repurposing of existing infrastructure for future fuels.

R&D Focus Areas: Pipeline design and integrity management, Safety and standards
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2020
RP3.2-08 Development of efficient and effective methodologies for the abandonment of pipelines

RP3.2-09: Bio-methane Impurities

This project aims to improve industry understanding of acceptable levels of trace biomethane contaminants within pipeline systems. It will study their potential interactions with existing gas pipeline / network impurities and review the standards and regulations that are relevant to their introduction. The production of these findings aims to reduce the technical risks behind the acceptance of biomethane into natural gas transmission lines.

R&D Focus Areas: Pipeline and network operations, Safety and Standards
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 11/2020
RP3.2-09 Biomethane Impurities

RP3.2-10: Hydrogen Pipeline Code of Practice
The AS 2885 series does not currently include hydrogen as an intended fluid within the scope of the standard, or address the specific considerations and risk associated with transport of hydrogen. The Australian pipeline industry will benefit from the guidance document developed in this project that addresses all the unique requirements relating to hydrogen, and provides recommendations for meeting the intent of AS 2885 in the design of a hydrogen pipeline, both for adoption of existing assets, future proofing of new assets for a future conversion and development of new hydrogen pipelines. The industry also benefits from understanding how to adopt hydrogen safely with both carbon steel and composite pipeline materials.
R&D Focus Areas: Safety and Standards, Pipeline design and integrity management, Pipeline and network operations
Lead Organisation: GPA Engineering
Funding: Future Fuels CRC
Status: In Progress
Start date: 07/2021
RP3.2-10 Hydrogen Pipeline Code of Practice: Design, Construction and Operation

RP3.2-11: Fitness for Service assessment of repurposed gas pipelines for hydrogen service
Introducing hydrogen in a pipeline is not benign and careful review of the existing pipeline suitability needs to be undertaken as failure of a pipeline carrying gaseous hydrogen can have severe consequences. To ensure safety and ease of operation and determine whether a pipeline has the structural integrity to withstand all forces which it might be subjected during operation, a condition assessment and a fitness for service assessment based on H2 transportation at different levels is required, as pipelines are not defect free. This research project aims at providing a literature review and assessing the suitability of the existing fitness for service and damage assessment methods used by the industry through AS 2885.3 standard and its approved guidelines.
R&D Focus Areas: Safety and Standards, Pipeline design and integrity
Lead Organisation: Worley
Funding: Future Fuels CRC
Status: In Progress
Start date: 10/2021
RP3.2-11 Fitness for Service assessment of repurposed pipelines to Hydrogen

RP3.2-12 Addressing hydrogen blending issues: gas mixing, demixing and hydrogen analysis
This projects expand the knowledge and technology supporting the transport and delivery of hydrogen/natural gas blends by considering two physically linked processes: mixing and demixing. Research activities relevant to mixing aim to develop guidelines for best practice. Parallel research activities aim to clarify the possibility, conditions and impact of mechanisms leading to a decrease in homogeneity.
R&D Focus Areas: Pipeline design and Integrity Management
Lead Organisation: Universities of Melbourne and Wollongong
Funding: Future Fuels CRC
Status: In Progress
Start date:10/2022
RP3.2-12 Addressing hydrogen blending issues gas mixing demixing and hydrogen analysis

3.3 Smart monitoring, data management and asset condition prediction

RP3.3-01: Gap analysis of smart monitoring and data analytics for fuel infrastructure networks
This project involved a literature review and industry survey in order to clearly identify needs, gaps and opportunities in smart monitoring, data analytics and asset condition prediction for fuel infrastructure networks. This project provided a roadmap for future projects to be undertaken under this theme.
R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP3.3-01 Gap analysis of smart monitoring and data analytics networks

RP3.3-02: Performance review of inspection techniques for un-piggable pipelines
This project aims to clarify current status and performance of techniques used for inspection and monitoring of non-piggable pipelines. The project develops guidance material for industry in terms of which tools are best used in specific applications and identifies potential knowledge gaps that require further research and development.
R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2020
RP3.3-02 Performance review of inspection techniques for unpiggable pipelines

RP3.3-04: Smart Sign technology for continuous easement interference monitoring
This project resulted in proof of concept for a smart visual sensor able to process locally (i.e. at the edge of the network) the live video feed of a CCTV to establish the level of threat associated with a pipeline encroachment and alert the operator of the pipeline in real-time.
R&D Focus Areas: Advanced manufacturing, Pipeline design and integrity management
Lead Organisation: Fleet Space Technologies, University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 08/2020
RP3.3-04 Smart Sign Technology for Continuous Easement Interference Monitoring

RP3.3-05: Demonstrating a new pipeline corrosion control technology
Corrosion under disbonded coatings (CUDC) has been identified to be a prime corrosion issue in the pipeline industry in Australia. This type of corrosion cannot be mitigated by cathodic protection (CP) and cannot be detected by normal inspection means other than expensive pigging and dig-up operations. Therefore, it is a critical need to develop technologies that could facilitate the detection, prediction and protection of CUDC. This project presents a novel technology that could be the first practical tool capable of CUDC control.
R&D Focus Areas: Pipeline design and integrity management, Advanced manufacturing
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2021
RP3.3-05 Prototyping and demonstrating a new pipeline corrosion control technology

3.4 Advanced infrastructure repair and protection systems

RP3.4-01: Retrofitting pipelines by in situ coating for protection against hydrogen permeation
This project aims to develop internal coatings for existing steel pipelines that can be applied in situ, cost effectively, without exposure or removal of the buried pipe. The coatings are being evaluated for protection against hydrogen permeation, to reduce the risk and incidence of hydrogen embrittlement.
R&D Focus Areas: Pipeline design and integrity management, Hydrogen Embrittlement, Advanced manufacturing
Lead Organisation: University of Melbourne
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 02/2019
RP3.4-01 Retrofitting pipelines by in situ coating

RP3.4-02: Closed-loop CP control system for fuel networks

This project studied the development of a closed control loop for real-time adjustment of cathodic protection systems for pipelines that experience coating damage. The closed loop system considers the dynamic nature of the environment to which assets are exposed. This new closed control system would be based on corrosion monitoring data from electrochemical probes that are unaffected by IR-drops across the soil.

R&D Focus Areas: Advanced manufacturing, Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 02/2019
RP3.4-02 Closed-loop CP control system for fuel networks

RP3.4-03: External Interference / Pipeline Damage Assessment – Phase 1

The project is the first stage in the development of a Centre of Excellence for External Interference and Pipeline Damage Assessment. The project involved an upgrade of an existing test rig to assess the risk of external interference by large scale Horizontal Directional Drilling equipment to pipelines and networks.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 12/2019
RP3.4-03 Centre of excellence for third party pipeline damage control

RP3.4-03B Damage to pipelines due to HDD equipment - Phase 2

Equipment used for horizontal drilling through the ground (HDD) presents a significant risk to pipelines. However, the risk is not well understood and there is no existing basis for estimating whether a particular type of HDD rig can penetrate a particular pipeline. In addition, there is the potential that high pressure natural gas pipelines will undergo a change to hydrogen service as the industry looks to decarbonise Australia's energy network. Therefore, understanding the interactions between hydrogen service and third-party impact damage and potential failure becomes vital in ensuring public safety. This research project provides the fundamental knowledge necessary to understand these interactions.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: University of Wollongong
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 07/2021
RP3.4-03B Understanding damage to pipeline due to HDD equipment – Phase 2

RP3.4-04: Keyhole coating damage treatment

This project develops streamlined methods for local coating repair and treatment that do not require uncovering the pipe. The research focus is on the development of corrosion mitigation fluids and a delivery method to inject them near coating defects along the pipe without the need to excavate, thereby allowing for potential cost savings of coating defect repairs.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 12/2019
RP3.4-04 Keyhole coating damage treatment

RP3.4-05: Validation of quality assurance tests for two-part epoxy coatings

This project uses a combination of standard and non-standard coating testing methods to evaluate, in a short period of time, the likelihood of premature failure of two-part epoxy coatings.

R&D Focus Areas: Pipeline design and integrity management, Safety and Standards
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **In Progress, interim reports available**
Start date: 06/2020
RP3.4-05 Validation of quality assurance tests for two-part epoxy coatings

RP3.4-07 Supplementary tests on the effect of bi-directional potential excursions on cathodic protection

This project conducted a short supplementary test program in order to better confirm and quantify the degree of the effect of cathodic transients under different conditions.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 08/2020
RP3.4-07 Supplementary tests on the effect of bi-directional potential excursions on cathodic protection

RP3.4-09: Performance review and survey of trenchless technologies and materials for pipeline rehabilitation and repurposing for future fuels

This project aims at performing an independent and critical review and analysis of existing and selected new trenchless rehabilitation technology and associated materials in order to understand and compare their performance and working principles. This will be achieved by comparing different products and test results reported in the literature and surveying industry experts for experiences of using these techniques on their performance and limitations for pipeline rehabilitation and repurposing for future fuels.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: **Complete, research available for download**
Start date: 01/2022
RP3.4-09: Review of trenchless technologies for pipeline rehabilitation and repurposing for future fuels

RP3.4-10: Literature Review of the Effects of Common Impurities Found in High Density CO2 Pipelines on the Rate of Internal Corrosion

Recent laboratory tests have shown that the corrosivity of high-density CO2 increases significantly when certain commonly found impurities are present. The relationship does not appear to be predictable with corrosion rates often being much faster than expected.

This literature review should provide a better understanding of what is already known regarding this phenomenon, allowing planning of the most valuable future research to undertake that will enable industry to better manage this risk.

R&D Focus Areas: Pipeline design and integrity management
Lead Organisation: Deakin University
Funding: Future Fuels CRC
Status: In progress
Start date: 09/2022
RP3-4-10 Effects of common impurities found in high density CO2 pipelines/