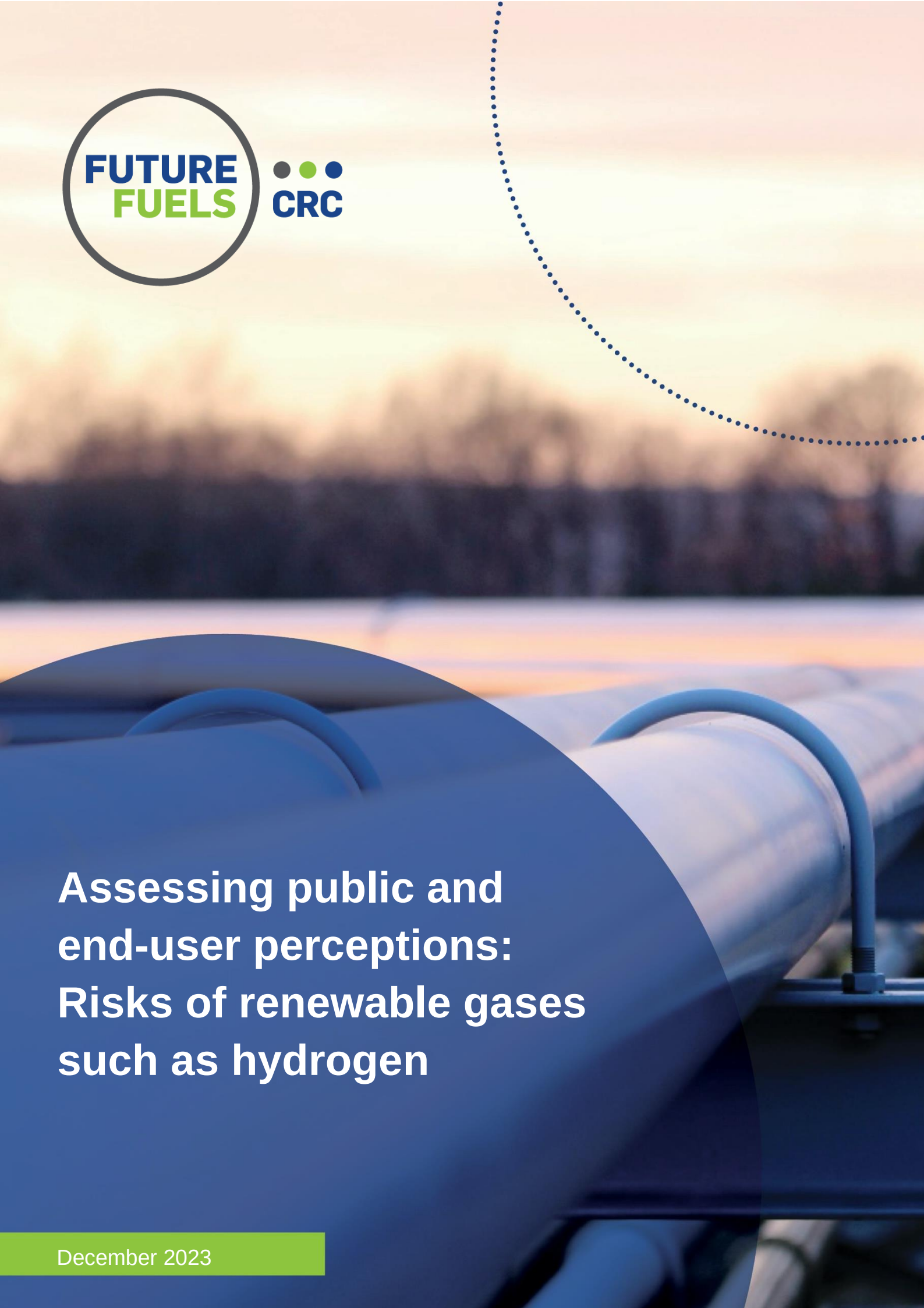

Assessing public and end-user perceptions: Risks of renewable gases such as hydrogen

December 2023

Project number: RP2.1-02

A social license and acceptance of future fuels

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IMPORTANT DISCLAIMER

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PROJECT INFORMATION	
Project number	RP2.1-02
Project title	A social license and acceptance of future fuels
Research Program	RP2
Milestone Report Number	9. Involving the public in project risk assessment – report on engagement and research findings
Description	This report provides the findings of three focus groups conducted with participants from Queensland, South Australia and Victoria in 2023. It shows the focus groups were effective in identifying the social and non-technical risks perceived by the public in relation to the introduction of hydrogen as a prospective low-carbon fuel
Research Provider	University of Queensland
Project Leader and Team	A/Professor Katherine Witt Dr. Amrita Kambo Mrs. Andrea Arratia-Solar
Industry Proponent and Advisor Team	Stephanie Judd - AGIG Jordan McCollum - APGA Michael Malavazos/ Lynette Day - SA Gov Nives Matosin - APA Ashley Kellet – AshleyK Consulting Ross Jamieson – Sitgas/GAMAA
Related Commonwealth Schedule	2.1.3 Report on attitudes of the Australian society toward the risks and benefits of hydrogen as an energy carrier.
Project start/completion date	Aug 2019/ Nov 2023
IP Access	**Open** – available publicly to all parties outside the CRC
Approved by	Ashley Kellett
Date of approval	18th December 2023

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Summary of Report

This report provides a conclusion to a research exercise that was designed with **the aim:** to identify where social and non-technical risks lie in relation to the introduction of renewable gases, and specifically hydrogen, as part of the transition to a low carbon economy. **An objective of the research was to** identify how the public can participate in formal project risk assessments and understand how the public (industry users and community) interpret expert information on the topic concerning the introduction of hydrogen in appliances, networks and pipelines.

The results seek to inform the development of effective risk communication programs by identifying the characteristics that trigger public concern and may lead to opposition or escalate into outrage. Identification of these risk factors and cultural values can inform risk communication strategies that may enhance perceptions of fairness and institutional trust when incorporated into operational procedures or policies.

Some key findings: based on a quantitative analysis several participants tended to refer to themselves as risk avoiders (see Section 5.1). Secondly, a majority of participants identified themselves as pragmatists who prefer to be persuaded into using a new technology. Despite this, the majority of participants in South Australia and Victoria indicated a willingness to trial blends of 10% hydrogen., based on the information they gained at the technical presentation and despite the detailed discussions around risk that followed thereafter. With 100% hydrogen, participants are less convinced (across the three cohorts), but success stories from demonstration projects worldwide could play a role in changing perceptions.
Based on the focus group discussions, it was found that people generally have high levels of trust in existing Australian standards for the handling and use of natural gas. Participants hold an expectation that similar rigour will be maintained and that standards will be put in place within a strong regulatory framework for gases such as hydrogen, similar to what is done for natural gas. As long as hydrogen can be introduced and managed so it does not present a greater risk to the public than natural gas, people said they would be OK with it.

Perceptions of technical risks (responses to the presentation) - The most frequently discussed risk was around the **potential for leaks and potential for harm to human health and natural environments -** and the public would need to be assured that these could be managed to a level that posed no greater risk than the use of natural gas.

Additional non-technical risks as perceived by participants - Participants acknowledged their own general **lack of awareness** of hydrogen properties, technologies, and safe use among the population that could lead to unsafe practices. Participants expressed an interest in gaining a better understanding of how the whole hydrogen ecosystem works, with particular emphasis on long term human and environmental safety. It would serve the industry well, if this need for further information was met via continued information and engagement campaigns, targeted at raising awareness amongst the general population.

Potential outrage factors - In accordance with the literature on risk perceptions, the results show that the public responds less to the seriousness of a risk than to such factors as trust, control, fairness, and courtesy. While participants generally reported feeling more comfortable with hydrogen technology after the technical presentation and focus group discussions, there were some risks identified that were thought to easily escalate to outrage if not managed well.

Assurances - However, participants relayed that many outrage factors could be met via an assurance that a strong regulatory framework is in place to manage production, transport, storage and end-use of the gas, and that people are well-trained on safe handling practices.

Involvement in project risk assessments - There is high expectation that end-users, as well as their neighbours and communities would have the opportunity to be engaged and consulted in relation to the introduction of hydrogen into gas networks and in relation to hydrogen projects in their neighbourhood.

Based on the key findings this report identifies the following **recommendations. There is a need for**:

A strong regulatory framework:
It was noted (as is common in discussions about hydrogen) that hydrogen's history is marked with (in risk terms) 'unwanted' events. The focus group discussions revealed that the public is seeking to understand the regulatory

and safeguard measures and new technologies in place that would act to prevent such accidents and catastrophes occurring in the future. At the same time, participants expressed having trust in existing regulations and Australian standards for the handling and use of natural gas and would expect that similarly high levels of standards and a strong regulatory framework would be in place for hydrogen **before it becomes introduced in a domestic or commercial context**. Many participants had the view that they would "be OK with" hydrogen as long as the regulatory framework could ensure it would be no riskier than natural gas.

Participants expressed considerable concern about the potential for leaks given the small molecule size of hydrogen and were worried about how much and how often the gas would leak, and if there were adverse health effects (regardless of ignition potential) from inhaling or coming in skin contact with the gas. Primarily, they were concerned about leaks in their home and residential buildings, specifically high-rise apartment buildings. They were also concerned about (potentially larger) leaks in the network (specifically in aged infrastructure and connections) and during transport. There was also concern about leaks during the production process and especially for the safety of workers. Participants wanted to understand what to expect if a leak should occur in each of these cases, how hydrogen behaves upon leaking and how people in proximity of a leak must respond to ensure personal and public safety. There were additional concerns about the storage of hydrogen, specifically how and where it would be stored and how that fitted into existing urban planning.

Risk communication strategies from trusted institutions:
Survey results show that a lack of awareness about hydrogen and its uses as a renewable energy source persists. Participants would like to see a "coordinated communication strategy" (where the messages are consistent) with collaboration from trusted institutions. A few institutions were named as those that people would trust as sources of reliable information to enable people to "weigh up the facts" on hydrogen risks and safety. These include Standards Australia, Chief scientists, independent assessments led by academic institutions, insurance companies' assessments of risk (appraisals for insurance premiums), the Australian Energy Regulator, certifying and governing bodies (such as the Australian Gas Association) and consumer advocacy groups. Participants said they would also like to hear from their energy retailers – specifically about what their vision and plans are around offering hydrogen as an alternative energy choice. Assurance would also be found in the existence of demonstration projects, particularly if those were made open to the public so they could "see firsthand" what the technology would look and feel like. The value of demonstration projects was discussed and many participants were very interested in learning from lessons and experience gained through demonstration projects within Australia and abroad.

Democratic and fair processes: Participants agreed that if hydrogen was to be introduced as a household fuel, they should be given the opportunity to opt -in or opt -out of accessing it. The choice would be based on their own assessment of risk, costs and benefits and personal needs and circumstances. Importantly, not having a choice, or having hydrogen introduced without their informed consent was identified as a trigger for community outrage. Additionally, many participants indicated they would be reluctant to be the first cohort to trial hydrogen, unless they could be convinced based on the experience garnered at demonstration projects elsewhere. It was communicated that if industry is planning to trial hydrogen in the home, project proponents must be respectful that not everybody will be willing to consider a trial at their home, unless sufficient evidence of hydrogen's success at demonstration projects is convincingly communicated. Therefore, sufficient time, planning and resources should be kept aside to seek and identify those willing consumers who may want to go first, given that success stories from demonstration projects begin to emerge.

Further engagement with commercial and industrial users: the research team found commercial and industrial gas users difficult to engage in discussions about hydrogen. This may be for a number of reasons, but those who did engage agreed that hydrogen is not a priority topic for most businesses at this point in time, even though there is a level of curiosity about what it might bring. The commercial and industrial gas users who participated had many detailed technical and economic questions about the application of hydrogen in their business and were keen for further information. All who participated were interested in decarbonising their operations and saw hydrogen blending or substitution as an option to consider. This group had high levels of trust in gas industry standards, regulations and appliance/machinery specifications although would need to be convinced these are all in place in equal measure for hydrogen.

1 Introduction

Hydrogen (alongside biogas production and carbon capture and storage) are termed as 'transformational technologies' in their potential role of decarbonising gas use in the residential and industrial sectors in Australia (Deloitte, 2017, p. 12). From a technical perspective alone, risk is defined as a product of the likelihood and severity of an adverse event occurring. However public interpretations and understandings of risk can vary considerably from purely technical assessments. Since **RP2.1 A social licence to operate**, seeks to facilitate the adoption of low-carbon fuels by industry users and the community (Future Fuels Cooperative Research Centre, 2020), it is useful to gain an understanding of public perceptions of risk in relation to hydrogen use.

Understanding and anticipating people's responses to hazards and their management can help reduce social licence barriers that lead to expenditures, delays, frustration, and enmity (Slovic et al., 1982). Understanding perceptions of risk is important in designing risk communication that has the intention of producing an appropriate level of concern and action in response to hazards. For example, communications about bushfire risks are intended to encourage people to take the risk seriously, increasing levels of concern to motivate actions to be prepared and increase safety. In other cases, risk communication is intended to reduce levels of concern about a risk, especially where the likelihood or severity has been exaggerated or misunderstood. It is known that when laypeople become involved in risk assessment, they often make different judgments than experts as to which risks merit public concern and regulatory attention (Sandman et al., 1993). This is because 'the public responds less to the seriousness of a risk (or its knowledge about seriousness as obtained from the media) than to such factors as trust, control, fairness, and courtesy' (Sandman et al., 1993, p. 586). Together, these so-called 'outrage factors' are highly influential and make up a large part of what the public perceives, indicates and means by risk (Sandman, 1987).

In the context of introducing hydrogen as a renewable gas, it is important to first understand and anticipate what the general public (as potential renewable gas consumers) perceives as a risk and a hazard. Second, it is essential to understand what factors may trigger or contribute to 'outrage' and therefore present a social licence obstacle. Additionally, it is known that when it comes to introducing and communicating the risks of new technologies, early action produces maximum benefits in guiding the development of stakeholder relationships, improving communications materials (Bradbury et al., 2011), and ensuring quality interactions at the project level (Ashworth et al., 2010; Ashworth et al., 2015).

While technical risk assessments are a core element of evaluating and communicating project safety, comparing these with a social science perspective on risk can help to enrich risk communication and risk management, and importantly to identify and manage potential outrage factors.

The aim of this research is to identify and understand perceived risks (including social and non-technical risks) in relation to the introduction of renewable gases – hydrogen – as part of the transition to a low carbon economy. Objectives of the research were to identify how the public interpret and respond to a technical risk assessment and how they might participate in formal project risk assessments. The results seek to inform the development of effective and productive risk communication programs by identifying:

- Risks that merit public concern and so regulatory attention,
- Any outrage factors to inform risk communication strategies,
- Expectations for involvement and engagement in the introduction of renewable gases,
- Any cultural values that may help to enhance fairness and institutional trust and/or ought to be incorporated in operational procedures or policies.

2 Literature Review

2.1 HYDROGEN AND SAFETY

It has been argued that when excess supply of renewable electricity is used to produce hydrogen, it has the potential to increase flexibility in energy systems, absorb renewable electricity at times of excess supply and to provide backup energy at times of excess demand. When renewable hydrogen produced in this fashion is injected back into the natural gas grid, it allows overall greenhouse gas emissions from the gas grid to be reduced (Quarton & Samsatli, 2018). Apart from this scenario, hydrogen has multiple production and usage pathways – including fuel based production (i.e. from methane reforming, coal gasification and biomass gasification) and use in transport, synthesis of fuels (such as methanol, ammonia) and industry (for refining, steel production, chemical and manufacturing processes and so on) (Quarton et al., 2020). It has been proposed that public safety and hazard mitigation will come to play a vital role in the hydrogen economy research in the future (Kar et al., 2022). A note of caution is added that being an 'alternative technology', hydrogen (and/or biomethane) are too costly and too far off for widespread use in homes and small businesses (Wood et al., 2023). Some studies have concluded that hydrogen use for domestic heating is less economic, less efficient, more resource intensive, and associated with larger environmental impacts (Rosenow, 2022).

From a technical perspective it is believed that hydrogen can be introduced into natural gas distribution networks with no serious safety issues (Quarton & Samsatli, 2018), depending on the volumetric percentage of hydrogen added (Messaoudani et al., 2016). However, hydrogen safety test results, research procedures, primary experimental data, quantitative risk assessments, safety distance recommendations and regulatory formulations as a result are still emerging (Kar et al., 2022). When considering safety in the home, some safety concerns may arise around risk of leakage and ignition (Quarton & Samsatli, 2018) as demonstrated in a UK study exploring potential issues associated with trialling hydrogen in the home (Gray et al., 2019). Portrayal of hydrogen as a 'sensitive' gas (Gordon et al., 2022) and memorability of the Hindenburg experience (Kar et al., 2022) may exacerbate concerns around the volatility and flammability of hydrogen within the home (Lambert & Ashworth, 2018). It has been shown that existing domestic appliances are capable of burning hydrogen up to blends of 20 vol% with no modifications required (Hodges et al., 2015). Higher concentrations of hydrogen blends would require that household appliances be retrofit or replaced, placing an additional cost burden (Dodds & Demoullin, 2013) which may exacerbate public concern. However, a UK based quantitative risk assessment shows that with appropriate measures, the risks to consumers and the public from fire and explosions in a hydrogen system are comparable to the risk from the current natural gas system (Law et al., 2021).

In the case of industrial hydrogen use, safety standards are usually already in place for several industrial processes based on current knowledge of the physical and chemical properties of hydrogen (Dodds & Demoullin, 2013). However, in the industrial context, appliances are bespoke and designed for specific end-use. It is expected that bespoke hydrogen-fired appliances will need specialist engineering design and retrofit on a case-by-case basis to experimentally determine any potential technical safety issues arising from retrofitting (Panek et al., 2020). Quantitative risks assessments similar in nature to those conducted for domestic end-use are yet to emerge. Also missing are studies on the fundamental aspects of hydrogen/natural gas combustion bearing uncertainty and significant implications for new and retrofitted device design, control and safety measures (Panek et al., 2020).

Keeping in mind this uncertainty and gaps in technical information, it becomes imperative to also engage with domestic and industrial end-users to gather their perceptions on the risks of hydrogen to collect baseline social data within the Australian context.

2.2 THE VALUE OF SURVEYS TO EVALUATE SOCIAL AND NON-TECHNICAL RISKS

Since the early '80s studies in risk perceptions have been examining people's opinions to characterise and evaluate hazardous activities and technologies as safety has emerged and remained a major policy issue (Slovic et al., 1982). It is believed that people's perceptions and attitudes are determined by a variety of quantitative and qualitative characteristics including a hazard's degree of controllability, the dread it evokes, its catastrophic potential, and the equity of its distribution of risks and benefits (Slovic et al., 1982). Apart from such influences, it is also useful to gain insight into the way people deal with risks in a more generalised, individualised context (Meertens & Lion, 2008) as well as how they resolve personal decisions that involve risk and uncertainty (Weber et al., 2002). Psychological variables such as risk perception and attitude towards perceived risk have been measured using comprehensive surveys questionnaires where participants are asked to make gut level

assessments on the riskiness of situations (Weber et al., 2002). In contrast, the 'risk propensity scale' offers a short, easy-to-use questionnaire, to adequately measure an individual's general tendency to take risks (Meertens & Lion, 2008). The risk propensity scale in the context of this exercise, where the focus is on a technology and the risks it entails, offers a way to understand participants' underlying psyche, offering a way to ground their background and experience. Alongside the risk propensity scale, an 'innovator category' scale is also useful to understand participants and their response to the prospects of new technologies. The 'innovator category' scale measures an individual's tendency to adopt or reject a new technology based on 'innovativeness' or the willingness to change their familiar practices (Rogers & Rogers, 2003). In continuation of previous surveys conducted to test attitudes, it makes sense to also explore individual's attitudes around climate change, specifically in the context of hydrogen and ascertain levels of subjective knowledge and instrumental and experiential attitudes towards hydrogen (Arratia-Solar et al., 2023; Martin et al., 2021). Specifically, in the context of low carbon technologies, surveys have been developed to measure how the overall evaluation of a technology is tempered by expectations around safety, risks and environmental benefits (Huijts et al., 2019). In the past, even when a positive perception of environmental benefits is present (Huijts et al., 2012), people have opposed technologies (such as CCS) out of a concern for negative outcomes, safety and undue risks (Ashworth et al., 2019). A recent case in the UK demonstrates how opposition towards hydrogen on counts of safety issues such as leakage and a perception that the pipes will be brittle, played out in Whitby, UK where a hydrogen village was proposed (Lawson, 2022). The matter is seeking resolution as residents are now being offered a choice – opt in or opt out – of having to trial hydrogen in the home (Whitby - Your hydrogen village, 2023). It makes sense to test perceptions around safety, risks and environmental benefits alongside people's willingness to participate when hydrogen comes closer and closer to home.

2.3 THE VALUE OF FOCUS GROUPS FOR IN-DEPTH EXPLORATION

While surveys are a suitable method to allow statistical generalisation of findings to broader populations (Carr et al., 2010), focus group discussions are more suited towards inductive generalisations (Carr et al., 2010) and allow for the collection of qualitative data when there is a need to understand how people feel or think about an issue, product, service or idea (Krueger & Casey, 2015). Focus groups permit researchers to obtain perceptions on a defined area of interest in a permissive, nonthreatening environment (Krueger & Casey, 2015). Focus group analysis is systematic, sequential, verifiable, and continuous, so long as researchers stay committed and clear on the purpose of the exercise – which in this case is to identify perceptions around hydrogen safety and risk that merit concern and identify any pertinent cultural values in relation to outrage factors that may emerge through discussions.

2.3.1 Defining 'risk' and 'safety'

From a technical perspective, 'risk' is described as the likelihood of a hazard causing harm and a 'hazard' is something that has the potential to harm you (Middleton, 2017). In other words, risk is the combination between the probability of occurrence of an unwanted event and its consequence (International Organization for Standardization, 2002). Probabilities can be numerically defined, and risk is viewed as a technical construct which can be calculated (LaChance et al., 2009; Messaoudani et al., 2016; Tchouvelev et al., 2018). 'Safety' is defined as the liberation from unacceptable risk and considered a societal factor that cannot be measured (LaChance et al., 2009; Messaoudani et al., 2016; Tchouvelev et al., 2018).

Risk communication is difficult under ordinary circumstances and more so in cases where community concerns are not congruent with potential of actual harm (Burger, 2022) or numerically defined risks. As has been evidenced in the Whitby Hydrogen Village case where outrage, blame and strong resistance came to the fore (Lawson, 2022; Whitby - Your hydrogen village, 2023). If 'hazard' is considered a product of risk magnitude and probability, from a social science perspective, 'outrage' is considered a function of how much people feel that the authorities can be trusted and how much control over risk management is shared with affected communities (Sandman, 1987; Sandman et al., 1993). Risk, then is a sum of hazard and outrage (Sandman, 1987; Sandman et al., 1993). Sandman (1987) explains that when considering outrage, due consideration must be paid to multiple factors that can exacerbate or soothe outrage – for example, higher degrees of voluntariness and control, perception that processes are fair, honest and transparent communication can soothe outrage, especially if morality is not brought into the question and the technology is familiar and well-tested. Memorability of accidents, prospects of dreadful disease and illness and high mortality rates can exacerbate outrage. Complexity is added when the general public's perceptions differ greatly from those presented by the expert.

2.3.2 Determining what risks are significant and how perceptions may differ

Based on Sandman's perspective, it is relevant to elucidate what the public may consider significant about the risk of hydrogen and differentiate it from what an expert may consider significant about the risks of hydrogen. Therefore, introducing communication between an expert (who is likely to assess technical risks) and the general public (who may assess the risks in their own individualised manner) becomes a crucial component to kick-start an informed discussion on hydrogen safety and risk. Besides offering a firm base for grounding discussions, expert presentations embedded within focus groups also allow researchers to explore the effect of message framing about risks, benefits and prospective project locations (Carr-Cornish & Romanach, 2014). Specifically, in the case of Australia where general awareness around the technology is low (Ashworth et al., 2021; Kambo et al., 2023a, 2023b; Martin et al., 2021), the role of information provisioning becomes ever more critical, especially since uncertainty and unfamiliarity with the technology is high (Gray et al., 2019).

2.3.3 Determining what assurances are needed

Following on from Sandman's perspective around outrage factors, once it is known what factors possess the potential to seed conflict in relation to hydrogen technology, it is also important to identify what assurance measures can potentially diffuse conflicts if and when they arise. A recent UK study shows that literature around assurances is needed since discussions around control, fairness and fear of accidents have emerged in recent focus group discussion in the UK (Gray et al., 2019). In congruence with what the research indicated, the Whitby Case (Lawson, 2022; Whitby - Your hydrogen village, 2023) demonstrates how much UK residents value having control and choice, and how this need (for control and choice) can interfere in smooth implementation of projects, unless adequate assurance measures are in place. Pre-empting the nature of assurance needed through focus group discussion has the potential to save undue pain and cost down the track. 'Delays and cancelations are very costly in terms of public and private money, as well as in terms of reaching valuable carbon reductions' (Huijts et al., 2019 article number 2220).

3 Methods

Following on from the literature stated above, a mixed-method approach was designed to rigorously test risk perceptions around hydrogen and its safety and risks. Three online focus groups were planned with members of the general public from Queensland, South Australia and Victoria. The aim was to recruit 10-12 participants from each of these states to conduct three separate focus groups.

Three additional focus groups with commercial and industrial users of gas were also planned to target small businesses who source their gas from retailers. However, small businesses are notoriously hard to engage with and considerable effort was needed to recruit enough participants. Consequently, one single focus group was conducted with commercial and industrial gas users (see Section 4.2).

Focus groups agendas included a pre- and post- survey, technical presentation by an expert, and a series of questions to prompt discussion as follows.

3.1 PRE- AND POST- SURVEYS

Pre and post surveys were designed to test individual risk propensity using a published scale (Meertens & Lion, 2008) slightly modified to suit the context of hydrogen. An innovator category scale (Rogers & Rogers, 2003) and a baseline question to measure subjective knowledge of hydrogen and instrumental and experiential attitudes towards hydrogen were repeated from the national surveys (Arratia-Solar et al., 2023; Martin et al., 2021). Individual risk propensity using a modified and shortened version of the Weber et al. (2002) psychometric scale and Huijts et al. (2019) were added to measure risk and safety perceptions vs perceived general and environmental benefits. A few questions were added to test participants' willingness to trial hydrogen under various scenarios and conditions. A full list of survey questions is included in Appendix A. The surveys were purposefully designed to be very short as the main focus was to have adequate time for discussion during the focus groups.

3.2 FOCUS GROUP DESIGN

For reasons mentioned in Section 2, information provision was a vital component of the experiment. To ensure that this component was carefully designed, the following measures were taken:

3.2.1 Information provision

FFCRC research partners, with significant knowledge and awareness on the topic of hydrogen safety were approached to participate as technical experts. As a technical expert, the research partners' main role was to independently create the content for a presentation delivered live to participants during the focus groups. Content development was aligned to strategic advice and considerations raised by members of an industry steering committee (ISC). The presentation content was neutral and fact-based allowing participants to adequately form opinions and discuss their perception of risks and concerns around hydrogen use from their perspective as prospective end-users. The presentation included information on the specifications of current natural gas appliances and industry statistics on hazards, accidents and injuries. Hydrogen properties were explained and test results for blends up to 20 vol% hydrogen and their implications on appliance safety were explained to participants (i.e., no noticeable change to performance, amenity, safety and emissions are indicated for blends up to 20 vol%). A figure on the hydrogen supply chain showed how stored reserves of 100 % hydrogen might serve to stabilise the electricity grid. Fringe possibilities by means of which 100% hydrogen might come to serve domestic supply were explained (i.e., by means of high-pressure bottles, low-pressure metal hydride containers, generate hydrogen on-site, hydrogen vehicles). Recent results from quantitative risk assessments (Hy4Heat) and explosion test results in relation to identifying suitable safety measures for 100% hydrogen scenarios were explained to participants. The presentation and its content is included in full in Appendix B. Following the presentation, participants were able to ask the technical expert any questions that came to their mind.

After the live Q&A, the technical expert's role within the focus group concluded. Thereafter, remaining participants were invited to discuss a series of questions aligned to the research aim and objectives as follows:

3.3 QUESTIONS FOR GROUP DISCUSSION AND ANALYSIS

Table 1 shows the questions that were included to guide the discussions within the focus group. The questions were designed in this way to enable rigorous analysis thereby fulfilling the scope of the research exercise as shown in Table 1.

Table 1: Questions for focus group discussions and analysis

Aims and Objectives	Questions for focus group discussion	Analytical scope
Aim: to identify where social and non-technical risks lie in relation to the introduction of renewable gases, hydrogen, as part of the transition to a low carbon economy. **Objective:** to identify how the public can participate in formal project risk assessments and understand the way public (industry users and community) interpret expert information on the topic in relation to appliances, networks and pipelines.	Please think back to the presentation. How do you feel about the information that was presented? Why do you feel that way?	Identify risks in relation to appliances, networks and pipelines. Identify cultural values. Identify how public interprets expert information.
	Are there any other risks of using hydrogen you can think of that were not presented?	Identify risks in relation to appliances, networks and pipelines. Identify cultural values.
	If hydrogen were to be introduced in your neighbourhood, what risks would concern you the most?	Identify risks that merit concern. Identify cultural values.
	Thinking of the risks that concern you, what assurances would you need to alleviate your concerns?	Identify assurances and any cultural associations.
	How and from whom would you prefer to receive these assurances?	Identify assurances and trustworthy institutions or individuals.
	Thinking of the risks that concern you, what would exacerbate your concerns?	Identify risks that merit concern. Identify assurance measures that participants might seek out as a result.
	If you were feeling anxious about the introduction of hydrogen, how would you communicate your concerns and to whom?	Identify cultural values that may help to enhance fairness and institutional trust. Identify how public might choose to participate/ act out on concerns they hold, Identify how public might choose to participate/ act out w.r.t to seeking out assurances.

4 Recruitment and Sample

This section describes the sample and recruitment strategy deployed to find participants from amongst members of the general public (Section 4.1) and commercial and industrial users (Section 4.2).

4.1 MEMBERS OF THE GENERAL PUBLIC

Participants were recruited for three focus groups (one each for Queensland, South Australia and Victoria) with the help of a market research company. The market research company was requested to find participants who were existing users of gas –confirming how they use gas - whether cooking, water heating or space heating inside the home. A sampling frame (Table 2) was provided to guide recruitment as follows:

Table 2: Sampling frame

State	Sample size (quota)	Male		Female		Sample size (final)
		Employed	Other	Employed	Other	
Queensland	12	4	2	4	2	12
South Australia	12	4	2	3	3	10
Victoria	12	4	2	4	2	10
Total	**36**	**12**	**6**	**11**	**7**	**32**

Participants were paid an honorarium amount of 110AUD via GiftPay vouchers organised by the market research company. In order to be eligible for the honorarium, participants had to participate fully for the 2.5 hour sessions with responses docked for both the pre and post survey.

4.1.1 Demographic profile of participants

Despite provision of the sampling frame, the recruitment company was able to provide participants with the following demographic features (Table 3 and Table 4). Table 5 shows the education status of participants in comparison to state averages.

Table 3: Gender and employment status of participants

State	Male				Female			
	Quota		Final		Quota		Final	
	Employed	Other	Employed	Other	Employed	Other	Employed	Other
Queensland*	4	2	2	1	4	2	3	5
South Australia^	4	2	1	3	3	3	4	1
Victoria	4	2	5	3	4	2	0	2
Total	**12**	**6**	**8**	**7**	**11**	**7**	**7**	**8**

Table 4: Age distribution of participants

State	Age bracket					
	35-44	45-54	55-64	65-74	+75	Total
Queensland*	3	2	3	2	2	**12**
South Australia^	2	1	4	3	-	**10**
Victoria	3	1	3	3	-	**10**
Total	**8**	**4**	**10**	**8**	**2**	**32**

**One participant did not fill in pre-survey data. We used the market research company recruitment information to include the participant's age.*

^One participant did not fill in pre-survey data. We used the market research company recruitment information to include the participant's age.

Table 5: Education status of participants

Education Level	Queensland* (%)		South Australia^ (%)		Victoria (%)	
	Focus group	State Average	Focus group	State Average	Focus group	State Average
Year 10 or below	9.09	16.9	0	14.8	0	14.3
Year 11 or equivalent	0	4.4	0	9.8	10.0	6.1
Year 12 or equivalent	9.09	19.2	22.22	17.4	10.0	16.8
Certificate I or II	0	†	11.11	†	10.0	†
Certificate III or IV	9.09	19.9	33.33	19.7	30.0	14.9
Advance Diploma / Diploma	18.18	10.1	11.11	8.7	10.0	11.1
Bachelor or Honours degree	27.27	17.8	11.11	17.6	10.0	21.5
Postgraduate degree	27.27	6.0	11.11	6.3	10.0	9.2
Other	0	-	0	-	10.0	-
Total	**11**		**9**	**-**	**10**	

**One participant did not complete pre-survey, so we don't have their demographic data*
^One participant did not complete pre-survey, so we don't have their demographic data
† This average (%) is included in the education level "Year 10 and below." Source: https://www.abs.gov.au/statistics/people/education/education-and-work-australia/latest-release. *Highest educational attainment, Table 21*

4.1.2 Household energy profile (from Q&A Fieldwork)

At recruitment the market research company asked the participants to confirm

Q. Which of the following do you use in your household?

Participants responses are depicted in Figure 1 – showing that all participants were connected to electricity and gas grid. Majority of South Australian participants also had solar photovoltaic panels.

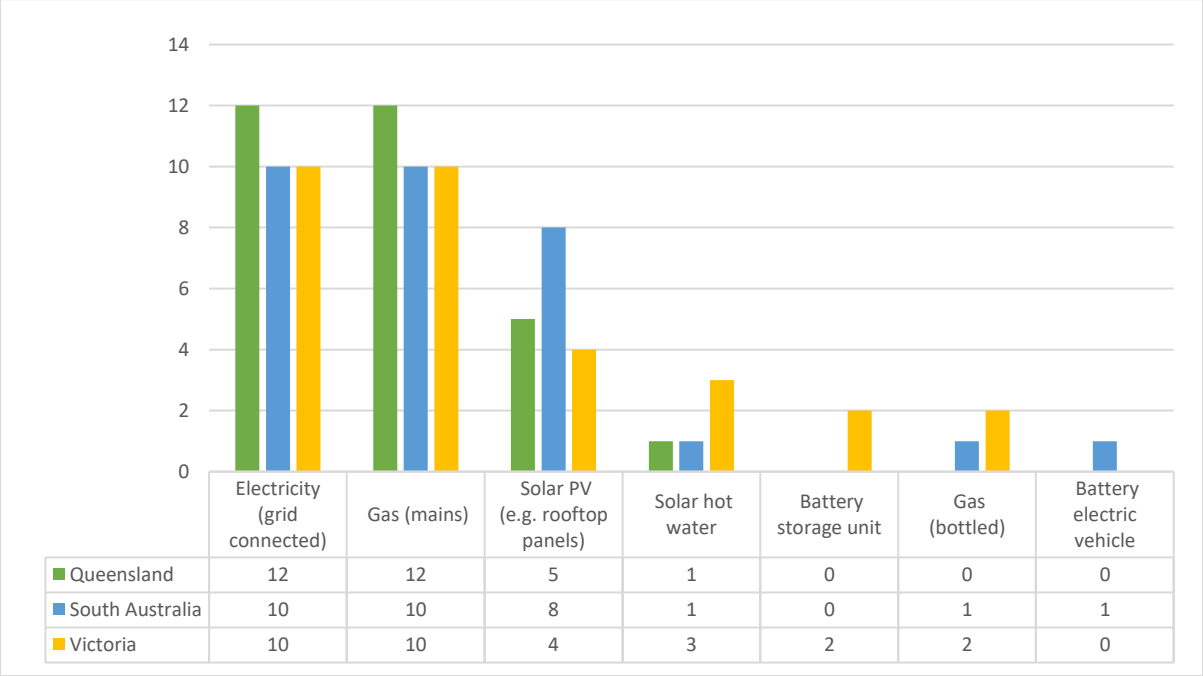
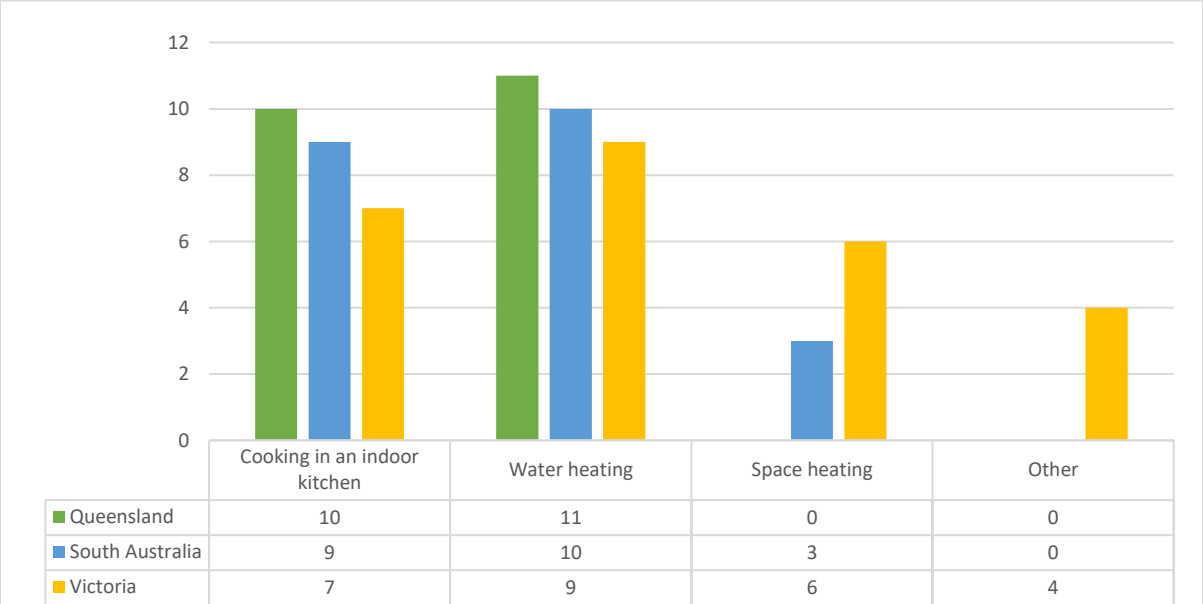


Figure 1. Energy sources in participants' households

At recruitment, the market research company also had to confirm how participants used gas in their home:

Q. What activities do you use gas for at your home?

The activities indicated by the participants as a reason for which they use gas include cooking, water heating and space heating (shown in Figure 2.)



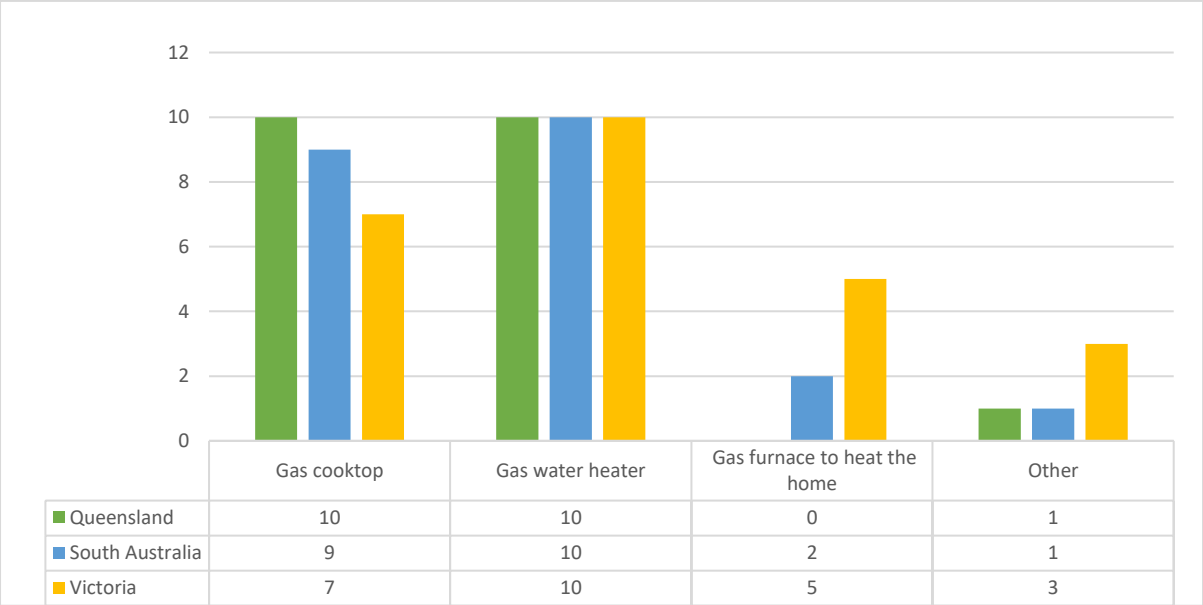
	Cooking in an indoor kitchen	Water heating	Space heating	Other
Queensland	10	11	0	0
South Australia	9	10	3	0
Victoria	7	9	6	4

Figure 2. Household activities where participants use gas

The last question the market research company asked participants was to confirm the gas appliances that participants use in the home:

Q. What gas appliances do you currently use in your household?)

Congruent with the indication from the previous question, participants noted that the gas-fired appliances they use are cooktops, gas water heaters and gas furnaces (Figure 3)



	Gas cooktop	Gas water heater	Gas furnace to heat the home	Other
Queensland	10	10	0	1
South Australia	9	10	2	1
Victoria	7	10	5	3

Figure 3. Gas appliances used in participants' households

4.2 COMMERCIAL AND INDUSTRIAL USERS

To find participants for this category of end-users, the aim was to purposefully recruit participants seeking the help of ISC and FFCRC networks to connect to likely participants via direct introduction. Secondly, the research team identified approximately eighty organisations likely to be 'gatekeeper organisations'. Gatekeepers are individuals or organisations who may have strong connections to internal colleagues, or external domains that interface with research population of interest (Tushman & Katz, 1980). In this case, gatekeeper organisations were identified as not-for-profit organisations or peak bodies that are currently active in the hydrogen research sphere or associations and corporations that are likely to have links with small business and/or energy retailers themselves. Emails were sent to management and/or administrative accounts associated with these organisations seeking their help in connecting us to likely participants. Emails were sent in between May to August 2023. Responses generated through this recruitment effort are summarised in Table 6. Two organisations agreed to participate in our research and the nature of their industry/ business are summarised in Table 7.

Table 6: Nature of response received from gatekeeper organisations

Response received from organisation	**Count of Organisations**
No response received.	57
A response was received but organisation could not offer any leads or make any relevant connections.	6
A response was received with some leads offered and connections made to individuals outside their own organisation to follow up with.	14
A positive response was received and an individual from the organisation was willing to participate in our research and brought along other members from their organisation to participate	2
Grand Total	**79**

Table 7: Participant profile

Industry/ nature of business activity	**Count of Organisations**	**Number of individuals participating**	**Reasons they use gas for**	**Example of gas fired appliances they use**
Manufacturing and supply of cast iron and steel products	1	1	Space heating, water heating and specialist processes such as heat treatment, equipment pre-heating, component drying and so on	Combustion burners
Automotive industry/ car repair centres	1	3		Baking ovens, spray booths, paint drying
Grand Total	**2**	**4**	**-**	**-**

Since participants attended this session without a reward, the total focus group time was reduced to 1.5 hours to respect participants' busy work schedules and in response to small group numbers. A date and time was selected based on mutual convenience of participants, technical presenter and research team. The technical presentation (Appendix B) was altered to suit commercial and industrial gas users rather than domestic gas users as noted in

Table 7. Pre and post surveys were also modified to suit a commercial and industrial context (Appendix A). The questions were kept the same (as shown in Table 1) with minor modifications to suit the context and results are summarised in Section 7. However, the number of participants for this group was too small to enable quantitative analysis of survey results. The next section therefore is limited to data obtained from focus groups held with members of the general public only.

5 Survey results: attitudes to risk, safety and hydrogen

5.1 RISK PROPENSITY SCALE

To measure individual participants' baseline attitudes to risk, the Meertens and Lion (2008) Risk Propensity Scale was used. Participants were asked:

Q. Please indicate the extent to which you agree or disagree with the following statements. Please do not think too long before answering; usually your first inclination is also the best one.

- I usually view risks as a challenge
- I really dislike not knowing what is going to happen.
- I take risks regularly.
- I prefer to avoid risks.
- I do not take risks with my health.
- Safety always comes first.

Participants could respond by selecting an option from 1 (= totally disagree) to 9 (= totally disagree). Participants responses are shown in Figure 4. From Figure 4 it is seen that there are large levels of agreement amongst the Queensland and South Australian participants with the statement "safety always comes first". There are large levels of disagreement amongst participants from all three cohorts with the statement "I take risks regularly".

A final statement from the Risk Propensity Scale was added:

- I view myself as a…

The participants could respond against a semantic differential scale where options ranged from 1 (= risk avoider) to 9 (= risk seeker).

Mean value of participants response to the statement is shown in Table 8.

Table 8: How participants view their risk propensity

I view myself as a 1 (= risk avoider): 9 (= risk seeker)	
Cohort	**Mean**
QLD	4.55
SA	4.22
VIC	4.60

When asked if participants viewed themselves as risk avoiders or risk seekers, the mean response shows a neutral position. A more detailed picture of the three focus groups' risk profiles is shown in Figure 4.

Figure 4: Participants' risk propensity

5.2 INNOVATIVENESS

To determine participants' 'innovativeness' based on 'diffusion of innovation' theory (Rogers & Rogers, 2003) participants were asked to select one statement closest to their view from options shown in Table 9:

Q. When thinking of your response to new technology, which best describes you? Please select the statement closest to your view

Table 9: Innovativeness

Statement	QLD	SA	VIC
I closely follow new technology and take risks by being the first to purchase it.	0%	0%	0%
I see the potential advantages in new technology and am one of the first to make use of its advantages and to profit from it.	18%	0%	20%
I am interested in new technology but at the same time I am pragmatic. I like to take time and be persuaded by the advantages. My decisions are (mainly) based on the recommendations of existing users.	82%	89%	50%
I am not thrilled by new technology, but rather appreciate security. It is safe to purchase a product when it has been on the market for some while and offers obvious advantages.	0%	0%	30%
I am traditional and have little affinity with new technology. I do not like changes in life and I purchase products only when the existing model I use is not produced anymore.	0%	11%	0%

We asked about innovativeness because those more interested might percieve more risk than the othesr.

Based on Table 9 majority participants identify with the statement (shaded in grey): *"I am interested in new technology but at the same time I am pragmatic. I like to take time and be persuaded by the advantages. My decisions are (mainly) based on the recommendations of existing users."*

This question was included in the survey to elicit whether risk averse participants would also be less accepting of new technologies. In the majority case, this might be true (as indicated in Table 9) but some variations in individual choices are evident, so the underlying assumption that risk averse individuals would also be less accepting of new technology do not necessarily hold true.

5.3 SUBJECTIVE KNOWLEDGE OF HYDROGEN

To assess participants subjective knowledge of hydrogen a question from the previous biogas and hydrogen survey was repeated (Arratia-Solar et al., 2023; Martin et al., 2021). Participants responses are shown in Table 10. Some observations worth highlighting - amongst Queensland participants, all participants indicated that they had heard of 'the use of fuel cells in vehicles', but none felt that they could describe it to a friend. In South Australia, participants did not feel that they could describe any aspect of hydrogen (noted in Table 10) to their friends. Many Victorian participants indicated that they had never heard of hydrogen prior to the workshop.

Table 10: Participants subjective knowledge of hydrogen

Statement	Queensland			South Australia			Victoria		
	I have never heard of it	I have heard of it	I know about it and could describe it to a friend	I have never heard of it	I have heard of it	I know about it and could describe it to a friend	I have never heard of it	I have heard of it	I know about it and could describe it to a friend
How hydrogen is produced.	0%	82%	18%	0%	100%	0%	10%	50%	40%
The use of hydrogen fuel cells in vehicles.	0%	100%	0%	22%	78%	0%	20%	50%	30%

Statement	Queensland			South Australia			Victoria		
	I have never heard of it	I have heard of it	I know about it and could describe it to a friend	I have never heard of it	I have heard of it	I know about it and could describe it to a friend	I have never heard of it	I have heard of it	I know about it and could describe it to a friend
The use of hydrogen fuel cells in homes.	55%	36%	9%	44%	56%	0%	50%	50%	0%
Hydrogen as an energy storage medium for electricity.	36%	55%	9%	22%	78%	0%	40%	40%	20%
Hydrogen refuelling station.	45%	55%	0%	56%	44%	0%	50%	30%	20%
Burning hydrogen as a replacement for natural gas.	36%	55%	9%	33%	67%	0%	50%	30%	20%

5.4 INSTRUMENTAL AND EXPERIENTIAL ATTITUDES TOWARDS HYDROGEN

Two questions have been repeated from previous surveys to measure how participants' instrumental and experiential attitudes towards hydrogen changed as a response to the technical presentation and focus group discussions (Arratia-Solar et al., 2023; Martin et al., 2021). Instrument attitudes are those relating to the perceived usefulness of hydrogen and experiential attitudes are those that describe emotional reactions and responses to hydrogen.

Q. Overall, do you think using hydrogen for energy in Australia would be …?
Q. When you think about the using hydrogen in Australia, please indicate how it makes you feel …?

A bipolar semantic differential scale was used to measure participants' attitudes towards hydrogen, presenting positive words on one side ('Very positive' = +3), and negative words with the opposite meaning on the other side of the scale ('Very negative' = -3). For example, respondents rated whether hydrogen for energy in Australia would be 'Very useful' (+3), 'Very useless' (-3), or somewhere in between, including 0 as a neutral value. Figure 6 shows how participants' responses changed before and after the presentation and focus group discussion.

Instrumental attitudes towards hydrogen changed from neutral towards positive for two states - South Australia and Victoria (Figure 5). However, some Queensland participants seem to hold reservations about the technology.

For experiential attitudes towards hydrogen, it appears that talking about the risks of hydrogen left a small number participants with more negative feelings (Figure 6). This is not entirely surprising given the topic for discussion, despite every effort to keep the discussion fact-based. For the most part however, feelings towards hydrogen became more positive and participants felt less concerned than they did before the discussions. This finding emphasises the balance needed in forthcoming risk communications on hydrogen technology.

Gas networks are more prevalent in South Australia and Victoria and an assumption is that gas as a source of energy is embedded more in the lives of the people in Southern states than in Queensland. In southern states, people's lifestyles are more reliant on gas (particularly for space heating) to create more ambient room temperatures in a colder environment. Therefore, it might be assumed that participants from southern states would have stronger responses to the introduction of hydrogen as a gas that might help to continue the option of using gas to sustain current lifestyles. Figures 4 and 5 supports this assumption as those participants who started out with 'neutral' outlooks towards renewable gas turn overwhelmingly positive in their outlook in the post-surveys. However, it is also shown that risk information provision can also push some people onto the negative side of the scale (as seen in Figure 5&6)

Participants' discussions reported in Section 6 explain perceptions of information and assurances needed and how participants would seek to have their needs met.

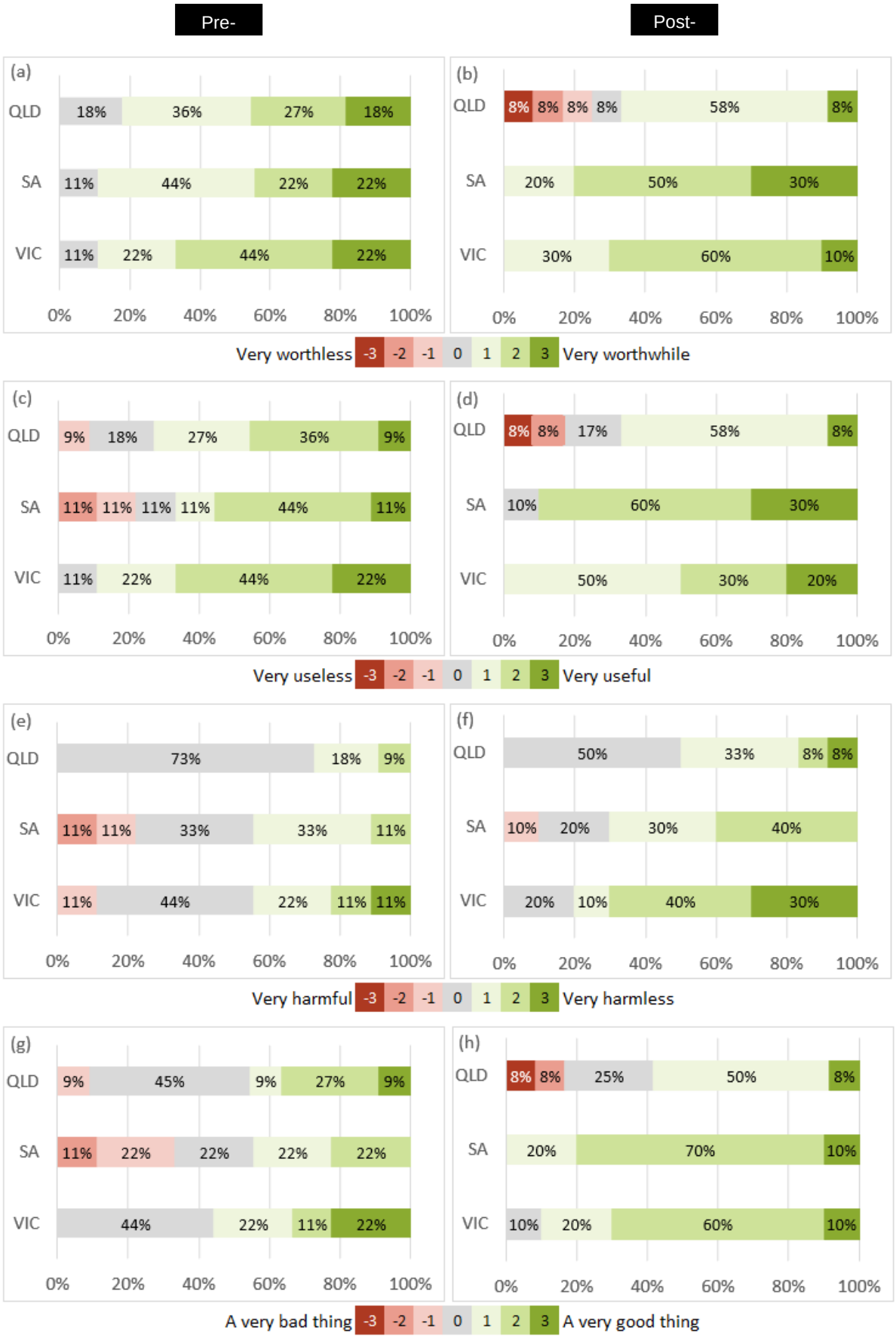


Figure 5. Overall, do you think using hydrogen for energy in Australia would be: (a), (c), (e) and (g) are pre-values; (b), (d), (f), (h) are post-values.

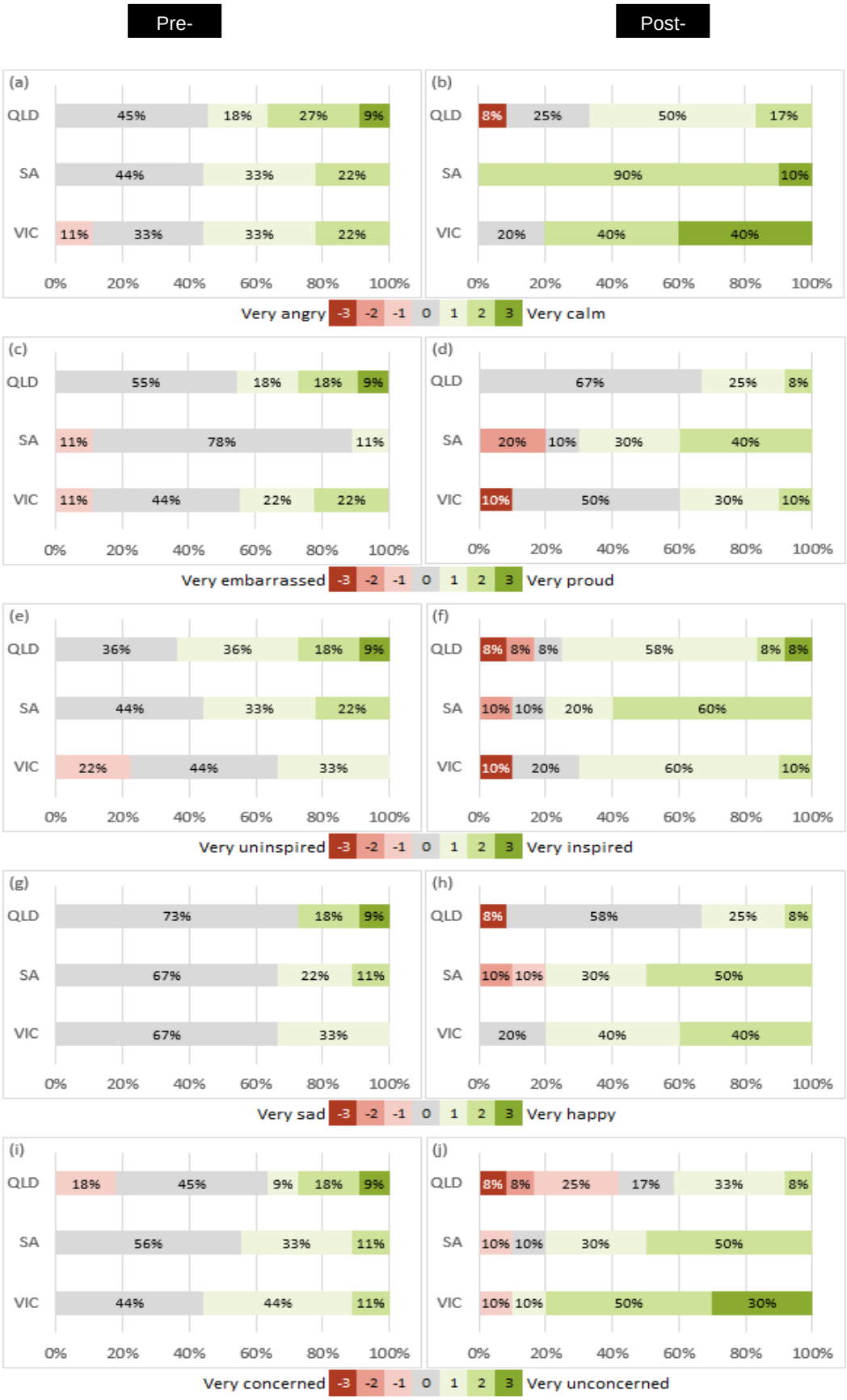


Figure 6. When you think about the using hydrogen in Australia, please indicate how it makes you feel? (a), (c), (e), (i) are pre-values; (b), (d), (f), (h), (j) are post-values.

5.5 RISK, SAFETY AND BENEFITS PERCEPTION

Two questions were asked in the pre- and post- surveys to measure participants' responses to four situations. The questions and situations were:

Q. People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is the possibility of a 'bad' consequences. However, riskiness is a very personal and intuitive notion, and we are interested in your gut level assessment of how risky each situation is. For each of the following statements, please indicate how risky you perceive each situation.

- Continue to use gas as is
- Switch to electrical appliances in place of gas appliances
- Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030?
- Stay on gas but switch to a 100% hydrogen gas supply by 2050?

Participants were asked to provide a rating along a scale from 1 (= not at all risky) to 3 (= moderately risky) to 5 (= extremely risking).

Table 11 shows the mean value of the participants' responses. Most of the responses lie between 1 and 3.17. This means participants perceive each of the above stated situations as low to moderate risk.

Victorian participants viewed electrification as the least risky scenario, whereas Queensland participants thought continuing to use natural gas was the least risky. Following the focus groups discussions, all groups viewed the introduction of a 10% blend of hydrogen as less risky than they did before the discussion, with marked differences seen in South Australia and Victoria (Queensland values went down marginally). Risk perceptions against 100% hydrogen gas fell for South Australia but increased for the other two cohorts.

Table 11. Pre and post-mean risk perception values by cohort

Situation	QLD		SA		VIC	
	Pre	Post	Pre	Post	Pre	Post
Continue to use natural gas as is?	2.00	1.92	2.89	3.10	2.33	1.90
Switch to electrical appliances in place of gas appliances?	2.64	2.25	2.33	2.60	1.56	1.50
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030?	2.55	2.50	2.89	2.10	2.44	1.60
Stay on gas but switch to a 100% hydrogen gas supply by 2050?	3.00	3.17	2.78	2.50	2.44	2.50

Weber et al. (2002) note that an inverse relationship between risk and benefit perception is frequently observed. (Individuals who perceive greater risks also anticipate lower benefits across a range of risky activities and vice versa). Weber et all. (2002) explain that this occurs when people rely on general affective evaluations to make risk/benefit judgments. Therefore, to balance and ground participants' response, another question was asked of the participants in relation to each of the above stated situations:

Q. For each of the following statements, please indicate the benefits you would obtain from each situation.

Participants were asked to provide a rating along a Likert scale from 1 (= no benefits at all) to 3 (= moderate benefits) to 5 (= great benefits).

Participants responses are shown in Table 12. Mean value of participants' responses range between 1 and 3.9.

In Table 11 and Table 12 (a situation where a 10% blend is introduced and a situation where a 100% hydrogen is introduced), South Australian and Victorian participants have perceived lower risk (mean values) and higher benefits (mean values) in comparison to Queensland participants. The indication is that South Australian and Victorian participants possess a more favourable assessment of 10 % blended hydrogen than their Queensland counterparts.

Table 12. Pre and post-mean benefit perception values by cohort

Situation	QLD		SA		VIC	
	Pre	Post	Pre	Post	Pre	Post
Continue to use natural gas as is	3.09	2.92	2.56	2.90	2.56	2.50
Switch to electrical appliances in place of gas appliances	2.27	2.83	3.11	2.80	3.22	3.20
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030	3.55	2.75	3.11	3.90	3.11	3.30
Stay on gas but switch to a 100% hydrogen gas supply by 2050	3.18	2.58	3.22	3.80	3.56	2.80

Since it is known that higher perceived safety risks are associated with a more negative overall evaluation of the technology and higher perceived environmental benefits are associated with a more positive overall evaluation of the technology (Huijts et al., 2019), another question was added in the post- survey:

Q. If there was an option to trial hydrogen in the home today, please help us understand how you would feel about hydrogen as a fuel? I feel that hydrogen as a fuel within my home would be:

Participants could respond with a 5-point semantic differential scale following the question to measure perceived risk: Very dangerous (1) to very safe (5). To measure perceived environmental benefit, participants could respond with five scales against the following variables:

- Will worsen air quality within my home (1) - Will improve air quality within my home (5)
- Much worse for global climate (1) - Much better for global climate (5)
- Much worse for global natural environments(1) - Much better for global natural environments (5)
- Much worse for Australia's natural environments (1) - Much better for Australia's natural environment (5)
- Much worse for my local natural environments (1) - Much better for my local natural environment (5)

Mean values of participants responses are shown in Table 13. Most responses sit around 3 indicating that participants hold a largely neutral position towards perceived risk and perceived environmental benefits. But again, South Australian and Victorian participants have returned a more positive evaluation of the perceived environmental benefits than Queensland.

Table 13. How participants feel about trialling hydrogen at the home - mean values by cohort

I feel that hydrogen as a fuel within my home would be	**QLD**	**SA**	**VIC**
Very dangerous (1) - Very safe (5)	2.67	3.60	3.60
Will worsen air quality within my home (1) - Will improve air quality within my home (5)	2.75	3.40	3.30
Much worse for global climate (1) - Much better for global climate (5)	3.33	4.60	3.60
Much worse for global natural environments (1) - Much better for global natural environments (5)	3.33	3.90	3.60
Much worse for Australia's natural environments (1) - Much better for Australia's natural environment (5)	3.08	3.90	3.60
Much worse for my local natural environments (1) - Much better for my local natural environment (5)	3.00	3.80	3.60

5.6 WILLINGNESS TO TRIAL

To test whether the risk-benefit evaluations would translate into a willingness to trial the product in their own homes, the following question was asked in the post- survey.

Q. Based on how you perceive the risks and benefits of hydrogen overall, if the following initiatives were offered for trial within your home, would you opt-in or opt-out?

Participants could respond with one of the following options:

- Yes, I would opt-in for a trial at my home.
- I don't know.
- No, I would opt-out of a trial at my home.

Participants responses are shown in Table 14. Aligned to results in the previous sections, South Australian and Victorian participants were more open to trialling 10% blend within the home with either retrofitted or new appliances. When it came to 100% hydrogen, participants were less convinced overall.

Table 14. Participants' willingness to trial hydrogen in the home

Initiatives	QLD			SA			VIC		
	Yes	I don't know	No	Yes	I don't know	No	Yes	I don't know	No
Trial a blend of 10% hydrogen in natural gas at my home with a retrofitted appliance?	50.0%	16.7%	33.3%	70.0%	20.0%	10.0%	70.0%	10.0%	20.0%
Trial a blend of 10% hydrogen in natural gas at my home with a new appliance?	50.0%	25.0%	25.0%	70.0%	10.0%	20.0%	80.0%	20.0%	0.0%
Trial 100% hydrogen at my home with a retrofitted appliance?	25.0%	25.0%	50.0%	30.0%	40.0%	30.0%	40.0%	30.0%	30.0%
Trial 100% hydrogen at my home with a new appliance?	25.0%	33.3%	41.7%	50.0%	30.0%	20.0%	50.0%	20.0%	30.0%

To summarise**,** despite the fact that participants tend to lean towards risk avoidance (see Section 5.1) and identify as themselves as being pragmatists who prefer to be persuaded into new technology (see Section 5.2), the majority of participants in South Australia and Victoria indicated a willingness to trial blends of 10% hydrogen, based on the information they gained at the technical presentation and despite the detailed discussions around risk that followed thereafter. With 100% hydrogen, participants are less convinced (across the three cohorts). To understand why participants, have reservations around 100% hydrogen, please see a detailed discussion in the following section (Section 6).

6 General public focus group discussions

This section presents a thematic analysis of participants' group discussions against each of the questions asked:

6.1 PARTICIPANTS RESPONSE TO THE TECHNICAL INFORMATION PRESENTED

The first question we asked participants was:

Please think back to the presentation. How do you feel about the information that was presented? Why do you feel that way?

Participants responses to these questions were classified into themes as follows:

6.1.1 I feel informed and it's a good avenue to explore…

Many participants responded positively to the technical presentation. They reported feeling "a lot more informed" about hydrogen and said that they "feel better for it". Based on the content of the presentation, participants thought it "sounds like a great idea" (Queensland participant) to introduce hydrogen into Australia's energy mix. For some, particularly if hydrogen would "turn out to be good for the environment", they were "all for it". Most participants saw the use of gas persisting in society, at least in some sectors (although others would prefer electrification) and the attraction of hydrogen was based on the notion that it would help to cut emissions, with some pragmatism and notes of caution thrown in:

"If hydrogen is very similar, but better for the environment, I'm all for it." (South Australia participant)

"If we can cut down the (fossil fuel) gas and bring the hydrogen, and I think it will be a great idea." (Queensland participant)

"From where I come from - We will need some natural gas in the system, anyway, you know, for base load, but also importantly, for agriculture and fertiliser production and other products that we need to produce. So, I think we're going to finish up with a whole mixture of things. And gas is going to be an important component of that. And I think, part of that component of gas will have certainly hydrogen in there…" (Victoria participant)

6.1.2 But, I need to know more…

However, despite appreciating the presentation and "feeling better" for being informed, participants noted that they were left with many more questions, as this was a complex topic with many aspects to consider such as safety and costs in relation to the production, storage, transport and use of hydrogen:

"Look, I think the presentation--- sort of left a lot of---questions as well. It's not all explained fully. There's a lot more, I'd like to know" (South Australia participant)

"Well, presented. The devil's in the detail... I think the reticulation of that gas...I'd like to see more detail about it" (Queensland participant)

"How safe is the storing of if? In bulk? (Queensland participant)

For example, in terms of hydrogen production, participants wanted to know, where and how would hydrogen be produced. Participants explained a need to be empowered and informed enough to be able to weigh up the claims around environmental benefits and safety for themselves, based on the proposed production pathways. There was also an interest in how and where the blending would occur and whether hydrogen could be produced at the home property scale (as is rooftop solar).

> *"I would have liked to have learned about how they produce the hydrogen… sort of like a comparison between how they produce gas and how they produce hydrogen. Just to weigh those up… I do worry about energy sources that take a lot more energy to produce than they create." (Queensland participant)*

> *"I'm curious with the generation of the hydrogen - what sort of I guess, how green would it be, if that's the main reason?" (Victoria participant)*

> *"You wouldn't be able to generate your own---hydrogen, would you?" (Victoria participant -* Context*: as you can do so with solar panels and electricity)*

Apart from wanting to understand the blending process better, participants also expressed a desire to understand the timelines of transition. For example, at what point of time would the vol % change and at what point of time would a change in appliances be triggered? There was discussion around the life expectancy of existing appliances and having enough time to decide which new appliance to purchase when needing to upgrade or replace an appliance. There were also concerns and questions raised about how a wider scale rollout of blended gas would unfold, given the distance issues and remoteness of some communities:

> *"Until we actually start to work out how we work through the distance issues in Australia, and the remoteness of some communities. I don't know how you roll some of this stuff out Australia wide. It's fine for places that are all connected to grids and gas networks and everything else … But how do we roll something out Australia wide?" (Victoria participant)*

6.1.3 The only thing is cost…

Invariably, the discussions circled around costs for consumers (and the taxpayer). Participants were concerned about the rising costs of living and energy affordability. Participants were concerned it would be "not worth the expense" and effort to "swap everything over" (meaning appliances, upgrades, and retrofits to the distribution networks), if it did not result in a cheaper energy alternative for consumers. It was perceived that hydrogen energy would have to "compete with electricity", and participants felt hydrogen would have to be significantly cheaper than other alternatives available in the market:

> *"It looks like it would be an expense to change over and yet no real cost benefits to people which I think is a shame." (Queensland participant)*

> *"I agree, like, yeah, for some people affordability, and they'll be that, you know, resistance to it because of the cost and things like that." (South Australia participant)*

> *"And it would really have to be significantly less than electricity for people to even consider it, especially if they don't even have the infrastructure there. So, I'm a little sceptical cost wise, but---otherwise quite enthusiastic about it." (Victoria participant)*

6.1.4 I am worried about…

In discussions about costs, some individuals expressed feeling "quite worried" about the costs and whether they would be able to afford the upfront costs of swapping appliances. This concern was exacerbated if they thought they would not be given a choice and the costs would be imposed on them. Others raised concerns about the cost of retrofitting current appliances and the disparity of impact between those who could afford it and those who would struggle. Others were worried about having to pay a higher price for blended gas, questioning whether the different blends would be priced differently. Importantly and overwhelmingly, participants were worried that as consumers they might not be offered a choice:

> *"If the government decides that my area is going to go hydrogen. Then they change over the distribution centre that I get my gas from and I'm then going to have to go out and buy other appliances and stuff like that, yes. Financially. I mean, we are on a fixed income. so financially, that might be improbable or impractical for us to do that at a given time" (South Australia participant)*

Other than costs, participants saw risks and expressed concern about safety aspects. For many participants, the fact that hydrogen is a small molecule was cause for concern where "it might have a tendency to leak more". Participants were specifically worried about leaks within the home, with the Queensland and Victorian groups specifically questioning if leaks would be adequately detected and managed in high rise buildings. It was also noted among the discussions that hydrogen has a lower ignition point and might be more explosive. Two participants mentioned hydrogen's reputation for being explosive, citing incidents such as the Hindenburg and the case of the hydrogen bomb to make their point:

> *"I think the reticulation of that gas, currently, if you put hydrogen in there because atoms are so small. If you have a small leak and gas when they go into your house, it's going to be a big leak with hydrogen." (Queensland participant)*

> *"So, I suppose initially, when you think of hydrogen. I think what comes to mind is sometimes the hydrogen bomb, and you go - Okay, safety, safety…"(Queensland participant)*

> *"There is a question still – safety. I mean, everyone knows about the Hindenburg. So, hydrogen doesn't have a good reputation for assuming that safety element is acceptable" (Victoria participant)*

In almost all discussions, the use of hydrogen for energy was compared with and "weighed up" against other energy options. One participant raised several issues and summed up many concerns in relation to the technology, all in one breath:

> *"…then to get the gas, you still use electricity to get gas (hydrogen). And so you're still mining coal to use the electricity to get the gas (hydrogen). And I don't know. I just think sometimes I don't know the answer, but I just sort of, hope it's not, because solar panels only last so many years, and they have mercury in them which we still don't know how to get rid of. And yes, they're good, and yes, they fix things. But in the long term we're going to have a disposal problem. And so we just, you need to look at, I suppose the pipes. And will the firefighters be able to help? You know it's a big thing to look for a city to change? Is it safe? Are our roads gonna blow up, you know, if it gets too hot, they haven't tested it in our climate? Is it reactive to temperature?" (South Australia participant)*

6.1.5 A Victorian concern

Victorian participants discussed the domestic use of hydrogen within a local context, where recent state government policy is urging Victorians to switch away from gas to electricity, with restrictions on new home constructions and other disincentives. For Victorians, there was discussion how the cost equation for continued use of gas, with or without a hydrogen blend, was being weighted towards electrification. There were concerns that once a critical mass had switched away from gas, the opportunity to introduce a cleaner form of gas would be lost. This was of particular concern to some participants who strongly preferred gas for cooking and heating. However, it was also noted how currently in Victoria, gas is "a far lot dearer than electricity". Therefore, the dominant Victorian view was that the domestic market would simply turn to electricity instead of gas with hydrogen if the current circumstances and messaging prevail:

"…They're actually offering us---incentives and rebates to shift from gas to electricity, which I simply won't do." (Victoria participant)

"…If electricity is already a bit on the front foot, hydrogen needs to speed up very quickly, or it will lose its day in the sun." (Victoria participant)

"…many projects that we work on in recent years, and we just see an industrial shift or clients are shifting---ditching gas all together, because, you know: it's infrastructure - gas is quite pricey for developers. And then for the moment, houses - They're just ditching it, I guess, as well... and that's really driven by cost as well." (Victoria participant)

6.2 PARTICIPANTS PERCIEVE RISKS BEYOND WHAT WAS PRESENTED

The next question we asked participants was:

Are there any other risks of using hydrogen you can think of that were not presented??

Participants responses to these questions were classified into themes as follows:

6.2.1 What happens if it leaks?

When asked about risks that were not presented, the discussion circled back to leaks. Responses to this question were focussed less on the size and occurrence of leaks (which was presented in the technical presentation) and more on what the implications of a leak would mean for them and the people around them, and in different situations. They wanted to know about safety practices and what scenarios they would have to face if a leak occurred close to them. Despite the technical information about leaks that was presented (and the safeguards that could be applied), participants were highly concerned about leaks. This concern led on to a desire to know more details about what happens when hydrogen leaks (how the gas behaves), and how it could impact people, property and infrastructure and the environment. Knowing that it was a smaller molecule, there was a perception that it would leak more frequently, and the leaks would be more problematic than natural gas:

"Leaks. Because hydrogen is so small it can get through any leak. So, if you got a leak, or even a tiny leak with natural gas, hydrogen is so small - The atoms, it'd be a major leak, so its leaks would be a real problem. The reticulation of town gas in Australia in Brisbane particularly is hundreds of years old, and it would leak like a sieve, I'd imagine" (Queensland participant)

Participants mentioned concerns about several conditions under which hydrogen could leak – holding specific concerns in relation to specific circumstances. For example, one participant was concerned that if hydrogen leaked out of the pipes, into the soil and then into the atmosphere, what would be the larger scale impacts on soil

and atmospheric health? In another instance, participants were worried about the impacts on human health. Participants questioned if hydrogen or its by-products were toxic, and if so, what were the risks of long-term exposure to even small amounts of leaked hydrogen? Other participants were worried about leaks in high rise buildings.

> *Has there been any studies done on the effects of hydrogen? Is it going to be more toxic in smaller amounts than natural gas or something like that. (Victoria participant)*
>
> *"…it's safety in people breathing it in, I suppose, for breathing something a by-product of it in, yeah…" (Queensland participant)*
>
> *"In fact, it has with that---little cloud above us. You know that little ozone layer issue. So, it's not just you know what happens to people breathing. It's what it's doing to the planet as well" (Queensland participant)*

In the instance that hydrogen leaked into people's homes, participants wondered what would happen if it pooled under their ceilings? Could it ignite from ceiling fixtures and would people still be able to smell it if it were high up under the ceiling?

> *"But when it starts to pool under your ceiling it's gonna come down eventually. But as it pools up on your ceiling. If you can't, if it's up there, you cannot smell it because it's up high. You turn the light on. Is that going to be an ignition point?" (South Australia participant)*
>
> *…"That's another thing too, is it going to spark?" (South Australia participant)*

6.2.2 Continuing Victorian concerns

Victorian participants continued to circle back to recent events in their state where people are being disincentivized to use gas. There was a concern that the hydrogen industry would not mature quickly enough, and most residents would choose to electrify rather than wait for hydrogen:

> *"It just goes back to what we were saying before that - if we're rolling out hydrogen, electricity is already there, etc., etc. you know the risk of spending all this money, etc. etc. And building a hydrogen industry that may never get off the ground. And it's a complete waste of time. Given that electricity may own everything. Again. It's just the risk of not moving quick enough…I just want to make it clear from my perspective. It's just the speed, the ability (for hydrogen) to overtake or not." (Victorian participant)*

Associated with the Victorian government's encouragement of electrification, Victorian participants also identified as a risk the propensity for governments to "take a position" on energy and favour one solution and then allocate resources to it, rather than being open to exploring all available alternatives.

> *"My concern is that in Australia, we always seem to home in on one or two options, I don't know why we aren't looking at other options like Scandinavia, that have got industrial incinerators that get rid of household waste that then generate electricity and heat sources and other alternatives. We just seem to always end up with whomever' s decided, something*

is a good idea, and we continue to go down that path without looking at stuff more broadly. So, I think there's a risk that we're not looking broadly enough to save ourselves…

Participants were concerned about the risk (or opportunity cost) of not exploring hydrogen as an option. Another risk identified was in relation to how new energy generation projects, such as hydrogen, will be built and whether it could be done without upsetting local populations:

Australia is very good at a NIMBY approach, not in my backyard. So, to sell hydrogen is something to go forward, and I understand. You know people say, let's do this quickly. I don't know how you actually get that to happen at places, because you know, how do you construct that energy source? In places that is not gonna upset people? Somebody's gonna have to do a selling job about how to construct them where?" (Victorian participant)

6.2.3 Risk of catastrophic events at home or storage sites

Participants raised concerns over potential for catastrophic events, wondering what the nature of these events could be, and how severe the accidents could get. They specially held concerns around the dangers that could eventuate at refuelling stations, underground storage tanks and so on:

"…if a car goes through the runs off the road, and careens through the front of your house at the main with gas appliances. You know it's got to be something really bad to set off explosions and things. I don't know what the scenario is with hydrogen? And the other thing is storage. They all mentioned storage and I'm not too sure whether that's a physical thing like a tank somewhere? And if that's the case, then you know, I think you have the potential for catastrophic issues there…" (Victoria participant)

6.2.4 Risk of admissions that have not come up yet – things we just don't know yet

Participants recalled their experience with other products that had been introduced in markets based on a belief that they were safe and what was known at the time. However, as experiences with those products evolved over time, safety issues continued to crop up and become known. Participants wondered whether those experiences will be repeated with hydrogen?

I know that we all thought gas was safe for years and years, and then we discovered that it's not so safe. I wonder whether that's the same for hydrogen? How long has hydrogen been used elsewhere? I would be worried about the admissions that---haven't actually come up yet. Things that we just don't know yet as far as it's safety…"

6.2.5 Risk of changing appliances

It was also perceived by some that changing appliances in itself was a risk, particularly in terms of the waste stream that would be generated, and the economic impacts on fixed and low income households. Further concerns were elucidated in relation to appliance changes as participants discussed the next question (Section 6.3.1.)

6.3 HYDROGEN IN THE NEIGHBOURHOOD – RISKS THAT MERIT CONCERN

The last question in this activity was:

If hydrogen were to be introduced in your neighbourhood, what risks would concern you the most?

Participants responses were classified into themes[1] below and salient aspects are highlighted as follows:

6.3.1 Concerns arising from a lack of awareness and understanding

When asked to consider the concerns in relation to their own neighbourhoods, participants circled back to several questions and doubts that were left in their minds after the technical presentation concluded. Although these conversations did not appear in the previous section, when participants began to relate the information back to their own neighbourhoods, several concerns resurfaced. These concerns were all rooted in participants' lack of awareness and understanding as they continued to grapple with the complex topics introduced in the technical presentation:

Although they had been introduced to key hydrogen facts, there were some points which they felt they did not understand well and other related concepts they thought were not touched upon in the presentation and that they wanted to learn about in order to understand better. They raised these points for further clarification and in some instances, participants were able to discuss amongst themselves and clarify points for each other based on what they heard at the presentation. Facilitators refrained from answering any questions and instead informed participants that the facilitator's role was limited to gathering participants concerns so as to inform and guide the process of risk communication. Participants requests for information are classified into themes as follows:

Questions in relation to appliances: Participants acknowledged the newness and uncertainty of hydrogen as a technology (in comparison to gas and electricity) relaying some discomfort around the 'unknown' factors.

> *"Yeah… I've never thought oh, I'm changing my appliances to gas, I wonder what the danger factor is there? But I am thinking about it now because this (hydrogen) is something unknown. I've never thought of it previously. Never even considered it..." (South Australia participant A)*
>
> *"… Yeah, it's an unknown, this whole hydrogen thing." (South Australia participant B)*

Participants were keen to understand the specific circumstances under which a change in appliances would be triggered. Although the technical presentation mentioned the appliances testing results, participants could not infer from these results, when and which household appliances would need changing. Noting the inconveniences around changing existing appliances, participants sought clarity around the specific circumstances, that would trigger a change or retrofit, seeking clear timelines with respect to the roll out of different blends:

> *"…So he never said, if you could use it for hot water services? (South Australia participant C)*
>
> *"Yeah, you can. Everything we've got now for gas we could use it for hydrogen, but only up to a, I think about 20%. After that, I wasn't too clear on it." (South Australia participant D)*

Questions about choice in receiving a blend: Participants, particularly those in Victoria, were very concerned about receiving a blended gas at home, especially if choice were taken away from them. They were very keen to be included in a consultation process prior to any roll out:

[1] Concerns around catastrophes arising from leaks remained in participants' minds and this topic drew a lot of conversation. In the interest of not repeating what has been previously reported, lines coded around this theme are not documented in this section.

"I can't see people accepting a mandated shift of any sort. It would have to be a consultation process (Victoria participant)

I'd be looking at it if I get a choice to look at it, or whether it then it's forced on me, I don't know. Is it something that we're going to be forced into going forward? Or is it something that we're going to have a choice for? (Victoria participant)

Participants also expressed concerns around the technical aspects of the blending process, wishing to know more about how it would all happen. The technical presentation mentioned two scenarios – one where a blend of up to 20% vol would be supplied and one where 100% hydrogen gas would be supplied. In the technical presentation, participants were advised that the use of 100% hydrogen would be a 'fringe possibility'. (See Appendix B, pg 41 and 57). Despite this, one participant stated that the jump from 20% to 100% seemed too extreme. They wished to understand the rationale behind why the two (a blend of 20 % vs 100%) scenarios were being considered. Another participant wanted to know what blend Australia would choose and when could consumers expect for it to happen. Another participant wished to know where blending would occur and whether any problems could occur with the blend. Participants also wanted to understand the difference in explosive risk for both scenarios:

"Where is the blending of the 20 and 80 done? Is it done, you know, outside our home or in the home? Do they blend together without any problems? Or is there some possibility of a problem in in that blend?" (Queensland participant)

"…If there's a leak in the house, and then a naked flame from something else, what's that explosive risk that comes along? And especially if we're talking 20% compared to 100% blend. So, that sort of thing in the home for me would be the biggest concern." (Queensland participant)

Questions in relation to insurance covers: Participants were concerned whether insurance companies would pay for any damages resulting from accidents if hydrogen were to replace natural gas:

"I know that I'm talking about things blowing up a lot. But if it (hydrogen) did have problems, would our insurance companies, they'd need to guarantee if we were going to switch over to it, or if we didn't have a choice, and it was what came in our pipes - would our insurance companies pay for burst hot water pipes because it was too hot or too cold? Or would they pay for a new oven if it melted rather than cooking?" (South Australia participant)

Questions in relation to houses – the finer details: Participants wished to understand whether their (kitchen) appliances would have to be moved around if hydrogen were to replace natural gas? Another participant was concerned about how junctions and connections to the houses would be managed or controlled, recalling their past experience with NBN rollout:

"Do we have to now move the stove to the window because of the fumes… it might have more toxic fumes?" (South Australia participant)

"…Just recalling with the NBN. I recall crews just go over and you know, sort of whack this massive, horrible box in front of your facade, or the fence, or your building or your shop or

business. And you know, it's this, yeah, this is not controlled, I suppose. And from the aesthetic point of view - it is terrible. It's these little details. I think that would be, yeah, a real bother." (Victoria participant)

Questions around how hydrogen will be transported: participants wished to understand whether there would be a need to transport hydrogen in ways other than in the pipes. If yes, what would the other modes of transport be and what could be the reasons for transporting hydrogen?

Questions around renting: participants who were renting indicated that they had little choice in the matter, and ultimately it would be their landlord who decides which appliances to install.

Questions around odorants: participants wanted to know whether the odorant would have a different smell and would they have to retrain themselves to recognise it?

"I guess we have to retrain our nose, I guess, because, like, in case of kids or dogs -smelling a gas leak and then getting the people out in time. They would not know if there was a different smell to it" (South Australia participant)

Questions seeking to understand why hydrogen will be a better option than electrification: Participants wanted to understand why hydrogen would be a better option than electrification.

"It just doesn't make a lot of sense at the moment. and I think that will be an enormous risk to the uptake, you know. Why would you go and buy new? I mean, for instance, if you got a gas hot water like I have, why would you go and spend money to get another hydrogen hot water system when you might be good off just going straight to electricity? That's I, just, you know, I'm not sure that they, that is, is going to be enough to talk people into it." (Queensland participant)

Questions around environmental impacts of renewables: A Victoria participant shared their experience with solar power and battery installations and raised concerns that even though the energy is renewable the production processes still rely on lithium mining and the products create extensive harm to the environment at the time of disposal. Would something similar also occur in the case of hydrogen?

6.3.2 Participants reinforcing the need for safety measures

Having aired their doubts as reported in the previous sections, participants reinforced their need for safety measures.

Recognising precedent - change from town gas to natural gas: Some participants recalled the time when town gas was replaced with natural gas. They believed that the pipes survived the change at the time and wondered what conversations occurred at the time. They believed a changeover to hydrogen could be negotiated in a similar way to what had happened in the past as long as adequate safety measures were in place.

The role of detectors and alarms: participants trusted that any changes to the gas system would have been thoroughly vetted from a safety perspective. Apart from stressing about who would bear the cost of installing safety measures, there were high levels of trust that no shortcuts with respect to safety would be taken, with a hope that government could offer assistance with installation cost of any new safety devices:

"But I just have such faith in scientists and people that I just don't think they'd be doing that unless there was a pretty high degree of safety. And it maybe then, we might have to install

special hydrogen sensors and that type of thing. I'd be happy to do that - smoke alarms are not that expensive. I hope that the hydrogen one would be similar." (South Australia participant X)

"Be nice if the government will do some sort of assistance around that so everyone does get the alarm - like it's a mandatory thing." (South Australia participant Z)

"If it maintains the safety standards as good as gas natural gases at the moment, then there is no need for the community to be concerned." (South Australia participant Y)

The role of educating people - using hydrogen safely: based on the technical presentation participants understood that hydrogen rises whereas gas sinks. Recognising the differences in the chemical properties of the gas, participants inferred that the gases could behave differently. Participants recognised that if handling practices were to differ, then public will have to be taught how to use hydrogen safely, just as they had been taught how to use natural gas in the past.

"So the education and awareness for this is has to be thorough, and it has to be slow and ongoing, so that people are taken on the journey." (Queensland participant)

"I guess nothing comes without a risk and as these things are introduced, there would have to be education programs. For example, we had to learn many years ago now - that if you can smell gas, you get up and jolly well go and turn it off because something's gone wrong. And that, you know, it's simply that education might have to be put in place as well as these changes (around added safety measures)." (South Australia participant A)

"We might need government programs to advertise on TV to understand it. It might cost a few, tens of millions of dollars, but they're going to have to be designed - if we have to change to that (hydrogen). (South Australia participant B)

The role of display homes: before hydrogen were to come in their neighbourhood, participants wanted to see it thoroughly tested out in display homes (that were ideally built away from well populated places).

The role of odorant: participants recognised that adding an odorant to hydrogen, so that it smells like rotten eggs would be an important safety measure, if hydrogen were to come to their neighbourhood.

6.3.3 Concerns around the need to upgrade pipeline infrastructure

Based on what they heard in the presentation, participants held concerns around how pipeline infrastructure would be upgraded. They were also concerned about the locations where upgrades to infrastructure would be needed and how these would impact their homes. Participants were concerned about the inconvenience caused if roads had to be dug up and questioned whether the overall benefits of the exercise would be worth all the effort:

"I know the pipes come through a lot of farms to South Australia, and then it gets distributed. So does it mean all of that piping has to be replaced, or do they have to line it…I'm in an old area…So they'd be digging up our road like they had to for the NBN, probably?" (South Australia participant)

6.3.4 A feeling that risks would be well managed

Having discussed their concerns amongst peers who shared their recollections of the safety measures indicated in the technical presentation, several participants reported that they would not be overly alarmed. Based on what they heard at the presentation, they interpreted that hydrogen would be much the same as gas and could be transported in pipes (or by other means) safely. A long as they knew where and how it was being produced, they would "be ok" with using it:

> *"I don't see although it's highly combustible and much more combustible than natural gas. I don't really see that there would be any problem---using existing gas pipelines to bring it down to Brisbane, for example. So, I don't see that as a major problem, I think it will be handled in much the same way as natural gas." (Queensland participant)*

> *"I was getting the impression that we could keep our existing appliances just switching over from our natural gas what we're using now to this hydrogen mixture so that there wouldn't be a cost for new appliances which would be significant, because if it was that simple - I would be more than happy" (South Australia participant)*

> *"As long as it, you know, is produced away from houses and residential areas, then I'm happy with it in the area." (Victoria participant)*

6.3.5 Concerns around incentives

Some participants held on to their concerns around affordability and felt that incentives would be needed to sway people, especially those people who reside in the hubs and are willing to try it before anyone else. Other participants recalled their experience with incentive programs around solar. They felt that public could be persuaded to forego concerns around risk if lucrative incentives were on offer, but that in the long run, it would not be viable for consumers from a cost perspective.

6.3.6 Concerns around acceptable levels of risk

Participants felt that they were comfortable with taking on risks with natural gas because over time they had gotten used to it. If the risks of hydrogen were compared to natural gas, they could come to accept them over time. However, if there were a change to standard, or they were asked to taken on a greater level of risk, they could get concerned.

> *I got the impression. It's more flammable than natural gas. And the chance of it leaking seems easier to do than natural gas, so I guess it's the difference between what we accept now is okay and acceptable for natural gas. And what is the increase or what's the increased risk with hydrogen … from what he presented it seemed pretty in the ballpark sort of thing. It didn't seem too extreme, that the risk was kind of quantifiably greater. So that's why I kind of felt comfortable that if it's within the parameters of what we already, you know. I think everyone's forgotten because we're used to using natural gas, you know, you don't have the risks spelled out anymore because we're so used to it. So introducing another fuel - you kind of are a little bit worried. But if you had a direct comparison with what we're already accepting, I think that's easier then to accept (Queensland participant)*

6.3.7 Concerns around cost

Fears around increased cost persisted amongst some participants. They were concerned about the cost of changing appliances and running costs, in the case that hydrogen was a more expensive fuel than other alternatives on the market.

6.3.8 Lack of willingness and trust

Some participants reported that they did not trust the system and could not imagine that safety would be a given. A Victoria participant felt that *"Australia is very good with the Not in My Backyard (NIMBY)"* approach, and asked how construction could actually happen in a way that did not upset people?

6.4 PARTICIPANTS SEEK ASSURANCES

The next question we asked participants was:

"Thinking of the risks that concern you, what assurances would you need to alleviate your concerns?"

Participants responses are explained as follows:

6.4.1 More information

Given self-reported lack of awareness and understanding, participants reiterated the need for more information about hydrogen. Participants sought out further information around the processes associated with hydrogen production, its storage, distribution, transportation and end-use. They sought to understand whether these processes could contribute towards emissions and toxins, and how the impacts on human or environmental health would compare to natural gas. They also sought to understand the impacts in context of the varying blend percentages being discussed. Although some participants relayed that they were comfortable with the prospect of the 10% blend, others were happy for it to go up to 20% blend. Others believed that the ramp up from 10 to 100 should happen slowly. Others relayed their concerns around blending, believing that it would perpetuate a reliance on fossil fuels.

In relation to participants' memories around Hindenburg, there was a need to know how hydrogen would be handled and managed in a modern context to avoid catastrophic events. Further around emergencies, there was a need to know whether firefighters will be adequately trained to deal with hydrogen accidents.

6.4.2 Safeguards against leakage

As participants had relayed their concerns around hydrogen leaks, they reiterated a need for assurance that careful safeguards would be in place to eliminate leaks altogether. They hoped that distribution networks would be properly lined and sealed, bearing in mind participants' concerns around environmental risk and human health. They hoped that homes would be thoroughly checked to ensure no leaks were present before hydrogen was used in homes. In addition, they hoped that sensors would be installed to ensure that leaks could be detected.

> *"Especially being in Australia - being so bushfire prone, that's not something we need - to add fuel to the fire" (Queensland participant)*

6.4.3 Thorough testing – academic rigour and research

Apart from installation of safety mechanisms to avoid and monitor leaks, participants reinforced the need for further testing to show that appliances would be able to withstand the stress of blends and/or 100% hydrogen over lengthy periods of time. They also wished to learn from the lived-in experience of demonstration villages where the blends had been tested for prolonged periods. They wished for these long term tests and studies to be validated/ authenticated by independent adjudicators:

> *"I'd want someone else to test it first---almost like a little village or something like that - that maybe had a different percentages happening in there with different appliances. So---like it was said, 10%,---20%. I don't know how you go up by then if you're going up by 10 or 5% through there? But maybe some willing participants to test what that might be like for 3 or for a year or something like that."*

6.4.4 Weighing up risks vs benefits and costs

There was some debate amongst participants about what they were worried about the most. For some participants the risks were secondary to the costs. To others, costs were secondary to safety. Some participants reflected that it was hard to consider risk without being aware of the benefits. Other participants reiterated that due to rising cost of living, no matter what the benefits of renewable gases, they felt that they would never be able to afford it and so *"it would never get off the ground for me".* Clarity around costs and information on benefits to consumers would be greatly reassuring in this context.

Participants felt it would be risky to impose any costs associated with the introduction of renewable gas onto vulnerable consumers (identified as fixed and low-income households, or those who were unable to understand the changes). They highlighted injustices that might occur between consumers who can afford new appliances and those who cannot.

6.4.5 Strong standards

Several participants agreed that having standards in place would be quite reassuring. Participants sought an assurance that specific standards would be developed and tested keeping in mind hydrogen's unique chemical properties. They further believed that no process would occur without a standard being in place for it – be it a process related to hydrogen production, storage, distribution, transportation, appliance installation, sensor installation, or any other. There is general trust in the standards and participants indicate that having strong standards in place for this new technology and ensuring compliance against standards would be an assurance of high regard.

6.4.6 Choice will remain on offer

Some participants needed an assurance that they would be allowed to have choice – whether to opt in or opt out of hydrogen use in the home. Specially participants with affordability concerns, wanted an assurance that they would not be made to use hydrogen per force. Participants reinforced that the if choice were removed, the risk of imposition would potentially develop into an outrage factor.

6.4.7 Australian ownership

Several participants agreed that it would be reassuring to know if the infrastructure were owned by Australians.

6.5 PARTICIPANTS SHARE WHO THEY WILL TURN TO AND WHY

The next question we asked participants was:

"How and from whom would you prefer to receive assurances?"

Participants responses revealed that they would seek several assurances from multiple sources in order to build trust in hydrogen technology. Trustworthy institutes for participants include:

Standards Australia – participants indicated that they would trust the institute responsible for creating standards for hydrogen technology to ensure that separate standards exists for the safe production, delivery, use of hydrogen. That standards would be present to confirm that the appliances are manufactured, installed and used safely.

Federal government fronted by a scientist – participants indicated the need to receive assurances from the federal government that hydrogen would be safe as a technology and that it would be green and good for the environment. They would expect to see scientists fronting federal communication campaigns. Participants noted that during COVID they had trusted government Departments of Health and Chief Health Officers as credible and trustworthy sources of information. With hydrogen, participants sought to understand what the equivalent entity would be?

Academic institutions – participants indicated that they would seek to hear from organisations such as CSIRO and universities to confirm that rigorous testing and evidence exists to validate claims that hydrogen is a safe technology.

Demonstration projects - Participants wanted to understand and learn what experience and evidence has been collected through demonstration projects being run in Australia and globally.

Insurance companies – participants noted that insurance premiums would be the best indicator on how safe hydrogen is within the home. If premiums stayed the same or went down, it would be an assurance.

Participants also expected that **Australian Energy Regulator, governing bodies, umbrella organisations and consumer advocacy groups** would be at the forefront of assuring that hydrogen is a safe technology to use. Participants expected that news about hydrogen would be delivered to Australian citizens via various channels, such as TV, social media, email, to ensure that all age demographics are receiving the current news. An expectation was placed upon **hydrogen retailers** to explain how billing systems would work if hydrogen was introduced into the home.

Participants also recognised the role **alarms and sensors** would play as material objects within the home that offer a sense of safety and security.

6.6 PARTICIPANTS SHARE WHY CONCERNS MAY EXACERBATE

The next question we asked participants was:

"Thinking of the risks that concern you, what would exacerbate your concerns?"

Participants responses reveal the conditions under which their concerns would exacerbate:

Lack of clear rationale justifying the costs and benefits – participants made reference to the many questions that remained in their mind around the environmental benefits of hydrogen technology vs the economic costs and environmental impacts associated with it. Participants indicated that lack of transparency around costs and environmental benefits would be a red flag for them. Participants needed to understand **why** hydrogen was being considered at all? Apart from lesser emissions, participants needed to understand why Australia must opt for hydrogen over any other cost-competitive energy source. A lack of clear explanation around why hydrogen is an option would exacerbate their concerns.

Lack of credible source of information – once again participants referred to government Departments of Health and Chief Health Officers and stated that if there weren't an equally trustworthy, credible entity to disseminate information about hydrogen, their concerns would exacerbate. Participants stated that lack of communication on hydrogen would worry them. Like themselves, participants expected that the public would need a lot of explanation around hydrogen production, storage, distribution, transportation, hydrogen safety and risk in the home; and long term health and environmental impacts.

Bad news about catastrophic events – participants indicated that accidents or bad news about accidents would exacerbate their concerns. Catastrophic events or frequent news of accidents would worry them. Negative media attention would certainly catch their attention.

Lack of thorough testing – participants acknowledged that hydrogen is a new and unknown entity to them and as yet there is no clear understanding of what the impacts would be to human health and the environment. If hydrogen were rolled out too soon, with an apparent lack of thoroughness and rigor in scientific testing, it would be a concern for them. Having placed their trust in the science, participants acknowledged that somewhere, someone could still miss something.

Lack of long-term prospects for hydrogen with respect to weak market forces and/or institutional instability – participants noted that apart from safety of the product itself, the success of hydrogen in the domestic market would depend on external factors such as a strong export market. As happened with LNG where the bulk of product was produced to be shipped overseas, participants worried that domestic prices/ supply would remain less assured, as domestic demand alone would not be enough to support development of hydrogen infrastructure at the required scale to bring prices down. There was also a concern around institutional stability compared to political stability. Victorian participants made a reference to the State Electricity Commission, wondering if a similar public body would be setup to participate in gas trading as governments can be voted in and out. Participants noted that that political tenures only last for a fixed number of years and questioned how this could affect hydrogen policy in the long term. Participants also wondered whether alternative

energy sources would overtake hydrogen in the meantime eventually making current development efforts redundant. Participants sought out clarity on who would own hydrogen infrastructure, showing a concern beyond the nature of the product (hydrogen) itself:

> *"…(is it) foreign ownership, commonwealth ownership or private ownership? Yeah, who runs these things and benefits from it? Who's you know? Who does it belong to? Those are the things that I think about as well. When I think about it, not just the safety of the product itself. But everything that comes with it. It's not just the product, it's everything attached to it - everything that can go wrong with it. That is, probably not about the product itself." (Victoria participant)*

Leaks and possible harm to human and environmental health – participants referred once again to the small hydrogen molecule and its implication on leaks. They stated that they would worry about what would happen to their own health and to the environment if there were leaks of any sort. In case a leak eventuated, participants wanted to know what would happen while they were waiting for repairs. How long would the leak take to repair, who would be responsible for repairs, and what would happen to them and their children. Participants were worried about the risks associated with climate change and how hydrogen technology could withstand future environmental conditions such as overheating, droughts, bushfires, and other extreme weather events. They also wanted to understand if hydrogen leaks could exacerbate these climate change effects.

Lack of choice – participants stated that a lack of choice (in being able to choose whether hydrogen is for them or not) would certainly exacerbate their concerns.

Lack of incentives – participants were mindful about costs and affordability and stated that they would worry if there were a lack of incentives to support them towards making a change (in the case that they desired a change for themselves but could not afford to pay for the cost of the change).

Lack of disposal strategies – participants sought to understand what the long-term implications on waste would be for hydrogen technology. They raised the example of solar panels, stating that they are great for now, but will eventually become a disposal problem later for consumers. If hydrogen technology had similar waste implications for consumers, it would eventually become a concern.

6.7 PARTICIPANTS SHARE HOW THEY WOULD COMMUNICATE CONCERNS

The last question we asked the participants was:

"*If you were feeling anxious about the introduction of hydrogen, how would you communicate your concerns and to whom?"*

As a response some participants indicated that they had complete trust that hydrogen would not be introduced into communities unless it was safe on all counts and it had been thoroughly tested for safety. They trusted that it would be regulated in much the same way as gas and accidents and injuries would be minimal. Having noted that, participants went on to discuss the formal processes and institutions that they would trust with their grievances, complaints and anxieties if these were to develop at any time in the future:

A good start – be involved in timely and genuine consultation: participants trusted and hoped that before any serious plans were made with distributing hydrogen in the domestic networks, they would be **consulted through a genuine consultation process**. They hoped that they would be **given plenty of warning** if such a roll out were to occur and that they would be given **a choice to opt in or opt out** of using it based on their own individual assessment of the product. They hoped these consultation processes would be a managed by local authorities such as councils and be conducted at multiple venues (such as shopping centres). Participants hoped that community engagement events would allow them to have **face to face interactions** with the experts, engineers, researchers and individuals representing all tiers of the government.

Trusted institutions and individuals in society: when it came to conducting the genuine consultation process or handling complaints and grievances post-facto, or rolling out widespread information and awareness

campaigns, some of the institutions that participants named as trustworthy included: a nominated institution like an **independent energy Ombudsman** and **federal or state ministries of energy**. Participants noted that they **would turn to local members of parliament and/or local councillors** to have their complaints heard and redressed, as participants felt elected individuals had an obligation to their electorate. A Queensland participant googled up information while the sessions were live and stated:

> *"There is a Queensland hydrogen task force and there's a lot of stuff under the Department of Energy and Works related to hydrogen. But it hasn't been well publicised, because obviously, it hasn't, because we haven't been told about it all or know about it. I did not know that."*

Involve themselves through independent enquiry to build their own knowledge and awareness – carrying on this theme, where participants noted their own lack of awareness, they stated that they would seek to educate themselves more on the topic. To fill gaps in their own knowledge participants stated that they would do keyword searches on Google, looking for **Frequently Asked Questions (FAQs)** on trusted websites such as **CSIRO**, the relevant **energy departments under federal and state governments**. In addition to FAQs participants wanted to learn about the experience of those people who have participated in **trials and long-term testing and safety** of hydrogen systems to see what issued had cropped up and down the entire supply chain. Participants wanted to also understand whether **energy retailers** were in consensus about the prospects and value of hydrogen. They wanted to understand the implications for the **first state** that chose to deploy hydrogen, the **changes to building approvals process** if they were to eventuate and the **readiness of the tradies** who would be involved in retrofitting / changing appliances and piping.

Trusted channels of communication – participants hoped that information and awareness campaigns would be via multiple channels so that people of all age groups can be included. A **hotline** similar to the one that was available for COVID would be appreciated. Participants said they would seek out **websites or emails** (to find the official complaints/grievances departments) where they could **get timely and appropriate advice** on the issues concerning them.

7 Commercial and industrial gas users' focus group discussions

Only four participants were present at this focus group making rigorous thematic analysis of the data untenable. Instead, this section is not based on counts and frequencies as in the previous sections but key points raised by the participants are summarised in response to each of the questions are shown in Table 15.

Table 15: Summary of participants responses

Q. Please think back to the presentation. How do you feel about the information that was presented? Why do you feel that way?
One participant perceived the mass production and availability of green, renewable hydrogen as a long way off. For this participant, conversion to hydrogen is seen as a longer-term project and capital expenditure has been allocated towards researching hydrogen into the future. For short and mid-term projects however, they are looking to electrify processes. Another participant shared that in the automotive industry, Electric Vehicles (EVs) are perceived as a stop-gap solution for the next 20 years. It is expected that cars will be powered by hydrogen in the future and become the norm over EVs.
Q. Are there any other risks of using hydrogen you can think of that were not presented?
There were concerns around the availability and amount of additional electricity needed to power electrolysers that will split water into hydrogen. There was also discussion and concern about the amount of water that would be needed for green hydrogen production, particularly given periodic cycles of drought and competing uses for water: "Water levels have been reduced in dams, and we've we can't water our gardens or wash our cars, so where's that supply of water going to come from?"
Q. If hydrogen were to be introduced in your neighbourhood, what risks would concern you the most?
Participants noted that the current standards for natural gas allows up to 10% hydrogen in the chemistry of the natural gas, anyway. Generally, if they were to receive a blended gas, they would have few technical concerns, as long as they *knew* what the chemistry of the natural gas coming in was. Once known, they felt they could handle it appropriately. One participant noted that their combustion burners are dated and recognized that if the gas went above that sort of 10% limit, a burner replacement program would need to be put in place, which would require significant expenditure. The costs associated with introducing hydrogen in small to medium sized businesses was also seen as a significant risk, but also an opportunity if it could be priced competitively and also enable decarbonisation. There was lengthy discussion about how the hydrogen blend would be metered and priced, and what associated costs there would be in the adaptation or replacement of equipment, and whether it would affect leases and property values. They would like to understand what benefits hydrogen might bring - could it improve fuel efficiency or reduce fuel consumption in any way? Most participants relied on certified gas technicians to maintain and service their equipment. It was discussed that there would be additional reliance on these 'experts' to alter the gauges and flows in the burners to adjust for the hydrogen blend, which may also be a hidden cost. There would also be "a huge reliance" on equipment manufacturers to determine what range of temperatures the equipment can tolerate, and whether the blended gas is going to cause damage to the equipment over long periods of time.
Q. Thinking of the risks that concern you, what assurances would you need to alleviate your concerns? ***Q. How and from whom would you prefer to receive these assurances?***
A participant stated that they would need assurance from the gas supplier that there is consistency with the percentage of hydrogen in the natural gas. A daily variation in hydrogen percentage could disrupt normal (optimal) operation of burners. The supplier would have to assure that they are going to "run between X percent and X percent, and that is within normal sort of standard deviation. Well, then, that's fine. We can handle those things."
Q. Thinking of the risks that concern you, what would exacerbate your concerns?

One participant commented that it would be “a big task” for the automotive industry to understand how their burners would operate with blended gas. For sheet metal manufacturers, there were concerns and questions about whether the hydrogen blend would heat and interact with metals in the same way as natural gas, and if there were risks in terms of changed properties in the metals that might affect its structural integrity.

The addition time and cost burden would exacerbate their concerns with the example given of having to involve external (or train internal) technicians to make sure that their equipment would be ready to accept a new blend. They wondered how disruptive that discovery process might be towards normal operation – citing that they have both old and new equipment to consider.

For these reasons, *not having enough lead time* would be a significant outrage factor for commercial gas users, along with the imposition of additional (upfront and ongoing) costs.

Q. If you were feeling anxious about the introduction of hydrogen, how would you communicate your concerns and to whom?

An automotive industry participant would contact their industry organisation (e.g. the Queensland Motor Trades Association) This kind of association exists in each state and would be their first point of contact if concerns were to come up at a regulatory level.

For on-site operations, trained and qualified gas experts would be called upon, such as gas technicians or equipment maintenance specialists and also the equipment suppliers. It was noted that a great deal of trust would be placed on these technicians to understand hydrogen properties and ensure that everything is working well when the fuel supply changes.

Another participant thought that they would reach out to the supplier of the hydrogen blended gas in the first instance. They explained how they rely on combustion engineers as expert subcontractors to calibrate their burners, check flue gas atmosphere and audit existing appliances and would trust that they knew enough about hydrogen. “So we know where we stand and what we need to do moving forward. So they they're the points of contacts - the experts.”

8 Conclusions and recommendations

This research examined how and understand how the public (industry users and community) perceive technical and non-technical risks in relation to the introduction of hydrogen in appliances, networks and pipelines, and how the public might be involved in project risk assessments.

8.1 KEY FINDINGS

Based on self-reported responses in the pre- and post-surveys it was found that participants tend to lean towards risk avoidance (see Section 5.1). Secondly, a majority of participants identify themselves as being pragmatists who prefer to be persuaded into new technology, rather than 'early adopters' (see Section 5.2). Despite these tendencies towards a conservative approach to technology and risk, the majority of participants in South Australia and Victoria indicated a willingness to trial blends of 10% hydrogen. Based on the information they gained at the technical presentation and despite the detailed discussions around risk that followed thereafter, they held minimal concerns. With 100% hydrogen, participants are less convinced (across the three cohorts), but success stories from demonstration projects worldwide could play a role in changing perceptions.

Based on the focus group discussions, it was found that people generally have high levels of trust in existing Australian standards for the handling and use of natural gas. Participants hold an expectation that similar rigour will be maintained and that standards will be put in place within a strong regulatory framework for hydrogen. As long as hydrogen can be introduced and managed so it does not present a greater risk to the public than natural gas, people said they would be OK with it.

Perceptions of technical risks (responses to the presentation)

The most frequently discussed risk was around the **potential for leaks**. Considerable concern about the potential for leaks in all aspects of hydrogen production, storage, transport and use. Particularly concern about leaks in the home and in residential high-rise buildings and health and safety implications. This concern would be exacerbated by weak standards and regulations, unreliable technology (detectors and valves), aged infrastructure (pipes and connections) and if an accident were to occur, but also if there was inadequate consultation and if consumers were not offered the choice to opt in or out. Participants acknowledged that they all at some point learnt how to use natural gas safely. Therefore, there is an expectation that the public 'will be taught' how to use hydrogen and blended gases safely. There is an expectation that the public will be taught what to do if they believe a leak has occurred – how to respond in a manner that ensures their own personal safety and the safety of the people around them.

Concerns were expressed about risks to **human and environmental safety** and the public would need to be assured that these could be managed to a level that posed no greater risk than the use of natural gas. For many, hydrogen was still associated with historical incidents and explosions. However, participants saw value in acknowledging rather than side-stepping these negative examples, but in combination with a clear explanation of what the learnings were, what has changed over time (e.g. advances in technologies) and the regulatory and safeguarding measures taken with the aim of preventing accidents.

Other technical risks were identified in relation to how hydrogen technology would withstand (and/or contribute to) potential effects of **climate change**, particularly excessive heat, rain and fire weather events.

Additional non-technical risks as perceived by participants

Many participants commented how the technical presentation highlighted for them how little they understood about existing gas networks in addition to their lack of knowledge about hydrogen. Participants perceived risks in relation to a general **lack of awareness** of hydrogen properties, technologies, and safe use among the population that could lead to unsafe practices. This risk was thought to exist at all points in the hydrogen value chain from production through to end-use. Participants expressed an interest in gaining a better understanding of how the whole hydrogen ecosystem works, with particular emphasis on long term human and environmental safety.

There was much discussion of the costs involved in introducing hydrogen. Risks were foreseen where the relative costs of producing, storing, transporting and distributing hydrogen had not been adequately considered, with some participants arguing for the inclusion of environmental and opportunity costs (in terms of water use)

into the overall cost-benefit equation for hydrogen. Mostly, risks were foreseen in relation to **additional cost burdens** for consumers if the price of gas was to increase, if gas appliances and commercial equipment needed upgrading or replacement, and if parts and maintenance became more frequent or expensive. There was concern about the effects these additional costs would have on fixed and low-income households and the sustainability of small to medium sized businesses.

How it would be decided (and by whom) which networks would have hydrogen blended, and which networks would be chosen first was also a risk identified in the focus group discussions. Participants felt it was important for those receiving a hydrogen blend (and their neighbours and community) to understand why their location was considered suitable. A **lack of consultation** and the opportunity to seek more information, and **not enough lead time** to be well prepared were seen as risks that could easily escalate to outrage and therefore hydrogen project risks.

Similarly, there was a general consensus that gas consumers should be given a **choice** about whether they receive a hydrogen blend or either remain on natural gas (if still available) or switch to electrical appliances. While most participants thought they would support or tolerate a decision to introduce hydrogen into existing networks and the broader energy mix, the imposition of hydrogen into the network, especially without consultation or explanation was viewed as a risk that would likely escalate to community outrage. Some participants were also quite adamant that they did not want to be the first to try a new technology.

Potential outrage factors

In accordance with the literature on risk perceptions, the results show that the public responds less to the seriousness of a risk than to such factors as trust, control, fairness, and courtesy. While participants generally reported feeling more comfortable with hydrogen technology after the technical presentation and focus group discussions, there were some risks identified that were thought to easily escalate to outrage if not managed well.

Firstly, communication (including public education) about hydrogen would be needed with specific training for those handling hydrogen but also for general consumers and community members. Participants perceived a general lack of awareness of hydrogen that could easily bring about unsafe practices, and opposition to a hydrogen project in their neighbourhood. An accident or injuries due to a lack of awareness or not enough consultation and preparation would be a trigger for community outrage.

Participants names several trusted institutions and organisations they would go to for information about hydrogen. However, they also recognised that there remains a degree of uncertainty around how hydrogen would behave in different applications and contexts. While consumers are seeking factual information, they also seek upfront acknowledgement of that uncertainty and assurance that measures are being taken to manages any risks that arise through uncertainty.

Control was another outrage factor identified in the data where participants strongly felt the need to be given a choice about how and when they might use hydrogen. This is linked with high expectations for consistent information and adequate consultation and lead time before any change is introduced.

This research has identified several risks that participants believe merit public concern. Participants generally have high levels of trust in current Australian regulations and standards to ensure safety in the use of natural gas and would expect the same to apply to hydrogen. Nevertheless, addressing the risks identified below will help to ensure a social licence for hydrogen. Risk communications should be designed to reduce the potential for community outrage and to assure citizens that sufficient regulatory attention has been (or will be) devoted to ensuring public and environmental safety in hydrogen production, storage, transport, distribution, and use.

Assurances

Participants reported being assured by a strong regulatory framework, similarly high Australian standards to the use and handling of natural and other gases, balanced information for trusted organisations and through successful demonstration projects.

Involvement in project risk assessments

There is high expectation that end-users, as well as their neighbours and communities would have the opportunity to be engaged and consulted in relation to the introduction of hydrogen into gas networks and in relation to hydrogen projects in their neighbourhood. They would need support in the way of information and education about hydrogen with upfront acknowledgement of any uncertainties. Where there are risks, they would rather know about them and be assured of the measures in place to ensure human and environmental safety than to not have the risks acknowledged. In the event of outrage brought on by perceptions of unfair process, inequity, or lack of consultation, people said they would most likely take political action and contact their local politicians.

8.2 KEY RECOMMENDATIONS

Based on the above stated findings it is clear that there is a need for:

A strong regulatory framework:
It was noted (as is common in discussions about hydrogen) that hydrogen's history is marked with (in risk terms) 'unwanted' events. The focus group discussions revealed that the public is seeking to understand the regulatory and safeguard measures and new technologies in place that would act to prevent such accidents and catastrophes occurring in the future. At the same time, participants expressed having trust in existing regulations and Australian standards for the handling and use of natural gas and would expect that similarly high levels of standards and a strong regulatory framework would be in place for hydrogen **before it becomes introduced in a domestic or commercial context**. Many participants had the view that they would "be OK with" hydrogen as long as the regulatory framework could ensure it would be no riskier than natural gas.

Participants expressed considerable concern about the potential for leaks given the small molecule size of hydrogen and were worried about how much and how often the gas would leak, and if there were adverse health effects (regardless of ignition potential) from inhaling or coming in skin contact with the gas. Primarily, they were concerned about leaks in their home and residential buildings, specifically high-rise apartment buildings. They were also concerned about (potentially larger) leaks in the network (specifically in aged infrastructure and connections) and during transport. There was also concern about leaks during the production process and especially for the safety of workers. Participants wanted to understand what to expect if a leak should occur in each of these cases, how hydrogen behaves upon leaking and how people in proximity of a leak must respond to ensure personal and public safety. There were additional concerns about the storage of hydrogen, specifically how and where it would be stored and how that fitted into existing urban planning.

Risk communication strategies from trusted institutions:
Survey results show that a lack of awareness about hydrogen and its uses as a renewable energy source persists. Participants would like to see a "coordinated communication strategy" (where the messages are consistent) with collaboration from trusted institutions. A few institutions were named as those that people would trust as sources of reliable information to enable people to "weigh up the facts" on hydrogen risks and safety. These include Standards Australia, Chief scientists, independent assessments led by academic institutions, insurance companies' assessments of risk (appraisals for insurance premiums), the Australian Energy Regulator, certifying and governing bodies (such as the Australian Gas Association) and consumer advocacy groups. Participants said they would also like to hear from their energy retailers – specifically about what their vision and plans are around offering hydrogen as an alternative energy choice. Assurance would also be found in the existence of demonstration projects, particularly if those were made open to the public so they could "see firsthand" what the technology would look and feel like. The value of demonstration projects was discussed and many participants were very interested in learning from lessons and experience gained through demonstration projects within Australia and abroad.

Democratic and fair processes: Participants agreed that if hydrogen was to be introduced as a household fuel, they should be given the opportunity to opt -in or opt -out of accessing it. The choice would be based on their own assessment of risk, costs and benefits and personal needs and circumstances. Importantly, not having a choice, or having hydrogen introduced without their informed consent was identified as a trigger for community outrage. Additionally, there remained many participants who indicated they would be reluctant to be the first cohort to trial hydrogen, unless they could be convinced based on the experience garnered at demonstration projects elsewhere. It was communicated that if industry is planning to trial hydrogen in the home, project proponents must be respectful that not everybody will be willing to consider a trial at their home, unless sufficient evidence of hydrogen's success at demonstration projects is convincingly communicated. Therefore, sufficient

time, planning and resources should be kept aside to seek and identify those willing consumers who may want to go first, given that success stories from demonstration projects are only just beginning to emerge.

Further engagement with commercial and industrial users: the research team found commercial and industrial gas users difficult to engage in discussions about hydrogen. This may be for a number of reasons, but those who did engage agreed that hydrogen is not a priority topic for most businesses at this point in time, even though there is a level of curiosity about what it might bring. The commercial and industrial gas users who participated had many detailed technical and economic questions about the application of hydrogen in their business and were keen for further information. All who participated were interested in decarbonising their operations and saw hydrogen blending or substitution as an option to consider. This group had high levels of trust in gas industry standards, regulations and appliance/machinery specifications although would need to be convinced these are all in place in equal measure for hydrogen.

9 Next steps and future work

The next step in this work package is to consolidate a final report documenting the key finding from all the surveys, citizens panels and focus groups that have been conducted within **RP2.1-02: A social licence to operate.**

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