



Appendices - Assessing public and end-user perceptions of risks of renewable gases such as hydrogen

October 2023

Project number: RP2.1-02

A social license and acceptance of future fuels

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Australian Government
**Department of Industry,
Science and Resources**

AusIndustry
Cooperative Research
Centres Program

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The team is also indebted to all participants who shared their experiences, insights and opinions in the focus groups.

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	Dr. Katherine Witt Dr. Amrita Kambo Mrs. Andrea Arratia-Solar
Industry Proponent and Advisor Team	Brent Davis - Jemena Stephanie Judd - AGIG Jordan McCollum - APGA Michael Malavazos/ Lynette Day - SA Gov Nives Matosin/ Klaas van Alphen - 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	TBC - Jemena
Date of approval	TBC

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Appendix A

PRE-SURVEY PUBLIC

Welcome to the workshop, please answer a few questions before we start.

Which workshop are you attending?

Wednesday

Thursday

Friday

To start with, please restate your Unique Identifier Code, which keeps your answers anonymous while facilitating the survey process. Please enter your:

Participant first name: _____

Home postcode: _____

Age: _____

What is your Gender?

Male

Female

Non-binary / third gender

Prefer not to say

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.

	Totally disagree	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree	Totally agree
Safety always comes first.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not take risks with my health.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer to avoid risks.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I take risks regularly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I really dislike not knowing what is going to happen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I usually view risks as a challenge.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I view myself as a

	1	2	3	4	5	6	7	8	9	
Risk avoider	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Risk seeker

When thinking of your response to new technology, which best describes you?

- I closely follow new technology and take risks by being the first to purchase it.
- 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.
- 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.
- 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.
- 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.

Do you believe climate change is happening now or will happen in the next 30 years?

- Yes, it is already happening.
- It will start happening within the next 30 years.
- No, it is not happening and won't.
- I do not know/ I am not sure.

How convinced are you that climate change represents a real problem for Australia?

- Very convinced
- Convinced
- Slightly convinced
- Neither convinced nor unconvinced
- Slightly unconvinced
- Unconvinced
- Very unconvinced

How much do you know about the following?

	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.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The use of hydrogen fuel cells in vehicles.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The use of hydrogen fuel cells in homes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydrogen as an energy storage medium for electricity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydrogen refuelling station.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Burning hydrogen as a replacement for natural gas.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If How much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or How much do you know about the following? [I have heard of it] (Count) >= 1

Overall, do you think using hydrogen for energy in Australia would be:

	-3	-2	-1	0	1	2	3	
Very worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very worthwhile
Very useless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very useful
Very harmful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very harmless
A very bad thing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A very good thing

Display This Question:

If How much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or How much do you know about the following? [I have heard of it] (Count) >= 1

When you think about the using hydrogen in Australia, please indicate how it makes you feel:

	-3	-2	-1	0	1	2	3	
Very angry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very calm
Very embarrassed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very proud
Very uninspired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very inspired
Very sad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very happy
Very concerned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very unconcerned

Display This Question:

If How much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1
Or How much do you know about the following? [I have heard of it] (Count) >= 1

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 '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. Provide a rating from 1 to 5, using the following scale:

	1 (Not at all risky)	2	3 (Moderately risk)	4	5 (Extremely risky)
Continue to use natural gas as is?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Switch to electrical appliances in place of gas appliances?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a 100% hydrogen gas supply by 2050?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If How much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1
Or How much do you know about the following? [I have heard of it] (Count) >= 1

For each of the following statements, please indicate the benefits you would obtain from each situation. Provide a rating from 1 to 5, using the following scale:

	1 (No benefits at all)	2	3 (Moderate benefits)	4	5 (Great benefits)
Continue to use natural gas as is	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Switch to electrical appliances in place of gas appliances	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a 100% hydrogen gas supply by 2050	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Which best describes the highest level of education you have completed?

- Year 10 or below
- Year 11 or equivalent
- Year 12 or equivalent
- Trade certificate or Apprenticeship
- Certificate I or II
- Certificate III or IV
- Advanced Diploma / Diploma
- Bachelor or Honours degree
- Postgraduate degree (e.g. Masters, PhD)
- Other (please specify) _____

Which of the following best describes your occupational status?

- Student
- Household duties
- Employed – Part Time
- Employed – Full Time
- Unemployed not looking for work
- Unemployed looking for work
- Retired
- Not able to work
- Other (please specify) _____

Which occupational sector do you work in (or worked in prior to ceasing work)?

- Agriculture, forestry, fishing
- Mining
- Manufacturing
- Electricity, gas, water, waste services
- Construction
- Wholesale trade
- Retail trade
- Accommodation and food services
- Transport, postal and warehousing
- Information, media and telecommunications
- Financial and Insurance services
- Rental, hiring and real estate services
- Professional, scientific, technical services
- Administrative and support workers
- Public administration and safety
- Education and training
- Health care and social assistance
- Arts and recreation services
- Other Services
- Not applicable

In which country were you born?

▼ Afghanistan ... Zimbabwe

Are you of Aboriginal or Torres Strait Islander origin?

- No
- Yes, Aboriginal
- Yes, Torres Strait Islander
- Prefer not to say

POST-SURVEY PUBLIC

Thanks for participating in the workshop, please answer a few questions before you leave.

Which workshop are you participating?

- Wednesday
- Thursday
- Friday

To start with, please restate your Unique Identifier Code, which keeps your answers anonymous while facilitating the survey process. Please enter your:

- Participant first name: _____
- Home postcode: _____
- Age: _____

After the presentation and group discussion, do you think using hydrogen for energy in Australia would be:

	-3	-2	-1	0	1	2	3	
--	----	----	----	---	---	---	---	--

Very worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very worthwhile
Very useless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very useful
Very harmful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very harmless
A very bad thing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A very good thing

After the presentation and group discussion, please indicate how you feel when you think about the using hydrogen in Australia

	-3	-2	-1	0	1	2	3	
Very angry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very calm
Very embarrassed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very proud
Very uninspired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very inspired
Very sad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very happy
Very concerned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very unconcerned

For each of the following statements, please indicate how risky you perceive each situation after the presentation and group discussion. Provide a rating from 1 to 5, using the following scale:

	1 (No at all risky)	2	3 (Moderately risky)	4	5 (Extremely risky)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Switch to electrical appliances in place of gas appliances.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a 100% hydrogen gas supply by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For each of the following statements, please reassess the benefits you would obtain from each situation. Provide a rating from 1 to 5, using the following scale:

	1 (No benefits at all)	2	3 (Moderate benefits)	4	5 (Great benefits)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Switch to electrical appliances in place of gas appliances.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stay on gas but switch to a 100% hydrogen gas supply by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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:

	1	2	3	4	5	
Very dangerous	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very safe
Will worsen air quality within my home	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Will improve air quality within my home
Much worse for global climate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for global climate
Much worse for global natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for global natural environments
Much worse for Australia's natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for Australia's natural environment
Much worse for my local natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for my local natural environment

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?

	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.
Trial a blend of 10% hydrogen in natural gas at my home with a retrofitted appliance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trial a blend of 10% hydrogen in natural gas at my home with a new appliance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trial 100% hydrogen at my home with a retrofitted appliance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trial 100% hydrogen at my home with a new appliance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial a blend of 10% hydrogen in natural gas at my home with a retrofitted appliance? [I don't know.]

Since you selected "I don't know" to *trial a blend of 10% hydrogen in natural gas with a retrofitted appliance*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial a blend of 10% hydrogen in natural gas at my home with a retrofitted appliance? [No, I would opt-out of a trial at my home.]

Since you selected "No" to *trial a blend of 10% hydrogen in natural gas with a retrofitted appliance*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial a blend of 10% hydrogen in natural gas at my home with a new appliance? [I don't know.]

Since you selected "I don't know" to *trial a blend of 10% hydrogen in natural gas with a new appliance*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial a blend of 10% hydrogen in natural gas at my home with a new appliance? [No, I would opt-out of a trial at my home.]

Since you selected "No" to *trial a blend of 10% hydrogen in natural gas with a new appliance*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial 100% hydrogen at my home with a retrofitted appliance? [I don't know.]

Since you selected "I don't know" to *trial 100% hydrogen with a retrofitted appliance*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial 100% hydrogen at my home with a retrofitted appliance? [No, I would opt-out of a trial at my home.]

Since you selected "No" to *trial 100% hydrogen with a retrofitted appliance*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial 100% hydrogen at my home with a new appliance? [I don't know.]

Since you selected "I don't know" to *trial 100% hydrogen with a new appliance*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen overall, if the following initiative... = Trial 100% hydrogen at my home with a new appliance? [No, I would opt-out of a trial at my home.]

Since you selected "No" to *trial 100% hydrogen with a new appliance*, please help us understand why you made this choice?

Based on your attendance at the workshop today, are there any thoughts and reflections that you would like to share with us in relation to the potential use of hydrogen in your home?

PRE-SURVEY COMMERCIAL AND INDUSTRIAL

Welcome to the workshop, please answer a few questions before we start.

To start with, please restate your Unique Identifier Code, which keeps your answers anonymous while facilitating the survey process. Please enter your:

- Participant first name: _____
- Home postcode: _____
- Age: _____

What is your Gender?

- Male
- Female
- Non-binary / third gender
- Prefer not to say

Please allow us to get to know you. When you think of yourself as an individual, 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.

	Totally disagree	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree	Totally agree
Safety always comes first.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not take risks with my health.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer to avoid risks.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I take risks regularly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I really dislike not knowing what is going to happen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I usually view risks as a challenge.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I view myself as a

	1	2	3	4	5	6	7	8	9	
Risk avoider	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Risk seeker

When you think of yourself as an individual, think of your response to new technology. Which statement best describes you?

- I closely follow new technology and take risks by being the first to purchase it.
- 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.
- 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.
- 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.
- 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.

As an individual, do you believe climate change is happening now or will happen in the next 30 years?

- Yes, it is already happening.
- It will start happening within the next 30 years.
- No, it is not happening and won't.
- I do not know/ I am not sure.

As an individual, how convinced are you that climate change represents a real problem for Australia?

- Very convinced
- Convinced
- Slightly convinced
- Neither convinced nor unconvinced
- Slightly unconvinced
- Unconvinced
- Very unconvinced

As an individual, how much do you know about the following?

	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.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The use of hydrogen fuel cells in vehicles.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The use of hydrogen fuel cells in homes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydrogen as an energy storage medium for electricity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydrogen refuelling station.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Burning hydrogen as a replacement for natural gas.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If As an individual, how much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or As an individual, how much do you know about the following? [I have heard of it] (Count) >= 1

Overall, do you think using hydrogen for energy in Australia would be:

	-3	-2	-1	0	1	2	3	
Very worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very worthwhile
Very useless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very useful
Very harmful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very harmless
A very bad thing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A very good thing

Display This Question:

If As an individual, how much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or As an individual, how much do you know about the following? [I have heard of it] (Count) >= 1

When you think about the using hydrogen in Australia, please indicate how it makes you feel:

	-3	-2	-1	0	1	2	3	
Very angry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very calm
Very embarrassed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very proud
Very uninspired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very inspired
Very sad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very happy
Very concerned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very unconcerned

Display This Question:

If As an individual, how much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or As an individual, how much do you know about the following? [I have heard of it] (Count) >= 1

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 '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 to be. Provide a rating from 1 to 5, using the following scale:

	1 (Not at all risky)	2	3 (Moderately risky)	4	5 (Extremely risky)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing new bespoke appliances suitable for 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If As an individual, how much do you know about the following? [I know about it and could describe it to a friend] (Count) >= 1

Or As an individual, how much do you know about the following? [I have heard of it] (Count) >= 1

POST- SURVEY COMMERCIAL AND INDUSTRIAL

Thanks for participating in the workshop, please answer a few questions before you leave.

To start with, please restate your Unique Identifier Code, which keeps your answers anonymous while facilitating the survey process. Please enter your:

Participant first name: _____

Home postcode: _____

Age: _____

After the presentation and group discussion, do you think using hydrogen for energy in Australia would be:

	-3	-2	-1	0	1	2	3	
Very worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very worthwhile
Very useless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very useful
Very harmful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very harmless
A very bad thing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A very good thing

After the presentation and group discussion, please indicate how you feel when you think about the using hydrogen in Australia

	-3	-2	-1	0	1	2	3	
Very angry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very calm
Very embarrassed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very proud
Very uninspired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very inspired
Very sad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very happy
Very concerned	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very unconcerned

For each of the following statements, please indicate how risky you perceive each situation after the presentation and group discussion. Provide a rating from 1 to 5, using the following scale:

	1 (No at all risky)	2	3 (Moderately risky)	4	5 (Extremely risky)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing new bespoke appliances suitable for 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For each of the following statements, please reassess the benefits you would obtain from each situation. Provide a rating from 1 to 5, using the following scale:

	1 (No benefits at all)	2	3 (Moderate benefits)	4	5 (Great benefits)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing new bespoke appliances suitable for 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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

	1	2	3	4	5	
Very dangerous	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very safe
Will worsen air quality within my facility	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Will improve air quality within my facility
Much worse for global climate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for global climate
Much worse for global natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for global natural environments
Much worse for Australia's natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for Australia's natural environment
Much worse for my local natural environments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Much better for my local natural environments

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

	Yes, I would opt-in for a trial at my facility.	I don't know.	No, I would opt-out of a trial at my facility.
Trial minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trial conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trial new bespoke appliances suitable for 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030. [I don't know.]

Since you selected "I don't know" to *trial minor modifications on controllers for your bespoke appliances*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030. [No, I would opt-out of a trial at my facility.]

Since you selected "No" to *trial minor modifications on controllers for your bespoke appliances*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050. [I don't know.]

Since you selected "I don't know" to *trial conversion kits and modified burner controls for your bespoke appliances*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050. [No, I would opt-out of a trial at my facility.]

Since you selected "No" to *trial conversion kits and modified burner controls for your bespoke appliances*, please help us understand what further information on hydrogen could help you decide one way or the other?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial new bespoke appliances suitable for 100% hydrogen by 2050. [I don't know.]

Since you selected "I don't know" to *trial new bespoke appliances*, please help us understand why you made this choice?

Display This Question:

If Based on how you perceive the risks and benefits of hydrogen, if the following initiatives were o... = Trial new bespoke appliances suitable for 100% hydrogen by 2050. [No, I would opt-out of a trial at my facility.]

Since you selected "No" to *trial new bespoke appliances*, please help us understand why you made this choice?

Based on your attendance at the workshop today, are there any thoughts and reflections that you would like to share with us in relation to the potential use of hydrogen in your facilities?

For each of the following statements, please indicate the benefits you would obtain from each situation. Provide a rating from 1 to 5, using the following scale:

	1 (No benefits at all)	2	3 (Moderate benefits)	4	5 (Great benefits)
Continue to use natural gas as is.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing minor modifications on controllers for your bespoke appliances, so that they are ready to receive a blend of 10% hydrogen in natural gas by 2030.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing conversion kits and modified burner controls for your bespoke appliances so that they are ready to receive 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Installing new bespoke appliances suitable for 100% hydrogen by 2050.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Which best describes the highest level of education you have completed?

- Year 10 or below
- Year 11 or equivalent
- Year 12 or equivalent
- Trade certificate or Apprenticeship
- Certificate I or II
- Certificate III or IV
- Advanced Diploma / Diploma
- Bachelor or Honours degree

Postgraduate degree (e.g. Masters, PhD)

Other (please specify) _____

Which of the following best describes your occupational status?

Student

Household duties

Employed – Part Time

Employed – Full Time

Unemployed not looking for work

Unemployed looking for work

Retired

Not able to work

Other (please specify) _____

Which occupational sector do you work in (or worked in prior to ceasing work)?

- Agriculture, forestry, fishing
- Mining
- Manufacturing
- Electricity, gas, water, waste services
- Construction
- Wholesale trade
- Retail trade
- Accommodation and food services
- Transport, postal and warehousing
- Information, media and telecommunications
- Financial and Insurance services
- Rental, hiring and real estate services
- Professional, scientific, technical services
- Administrative and support workers
- Public administration and safety
- Education and training
- Health care and social assistance
- Arts and recreation services
- Other Services
- Not applicable

In which country were you born?

▼ Afghanistan ... Zimbabwe

Q18 Are you of Aboriginal or Torres Strait Islander origin?

- No
- Yes, Aboriginal
- Yes, Torres Strait Islander
- Prefer not to say

Appendix B

PRESENTATION TO MEMBERS OF THE GENERAL PUBLIC



Hydrogen - domestic appliances

Outline:

- Gas appliances + hazards, accidents, injuries
- Hydrogen properties
- Blends up to 20 vol% hydrogen
- Hydrogen supply
- 100% Hydrogen appliances, safety, cost

1

Current gas appliances

Provide amenity (they deliver heat how you want it)



2

Current gas appliances

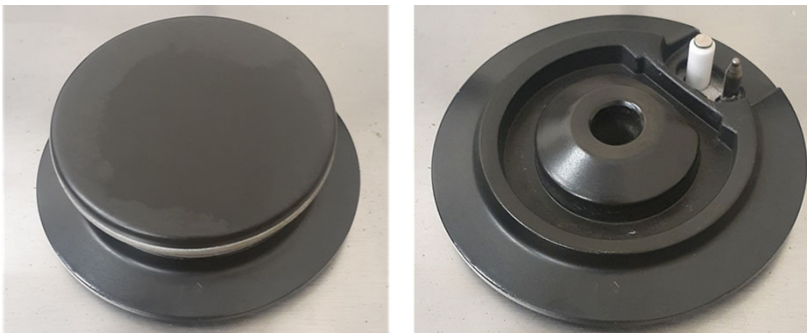
- Modern appliances have a flame sensor with automatic shutoff if flame is not detected
- This old cooker doesn't



3

Current gas appliances

- Example of a flame sensor on a cooker burner



4

Current gas appliances

Many other appliances are flued or located outdoors
And have flame sensing and automatic shutdown



5

Current gas appliances - Hazards

Hazards from accidental misuse or rare failures:

HAZARD	Cause	Protective measures
Unignited gas, potential explosion or fire, smoke	Leak	Installation and ventilation to Standards Flame detection Odorant Smoke, CO alarms
	Appliance ignition failure	
	External ignition source	



6

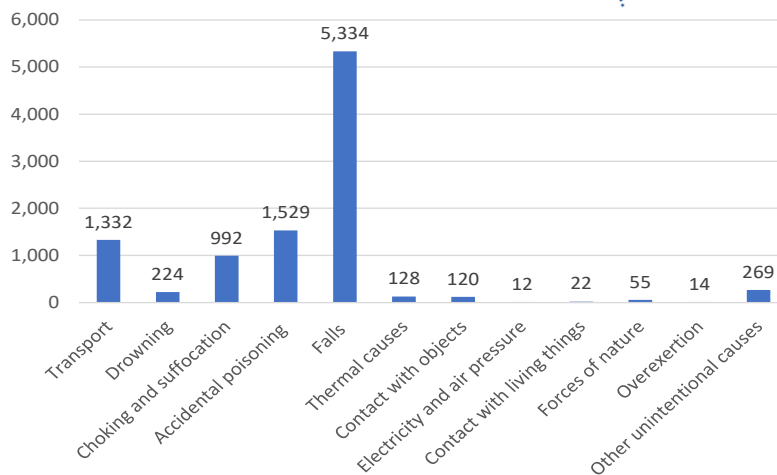
Current gas appliances - Hazards

HAZARD	Cause	Protective measures
Burns	flame or hot surfaces	Flame visibility Insulation Correct operation
Carbon monoxide	Poor combustion, quenching	Design and test to standards Proper operation and ventilation CO alarm
Nitrogen dioxide	High flame temperature	Design and test to standards. Proper ventilation.



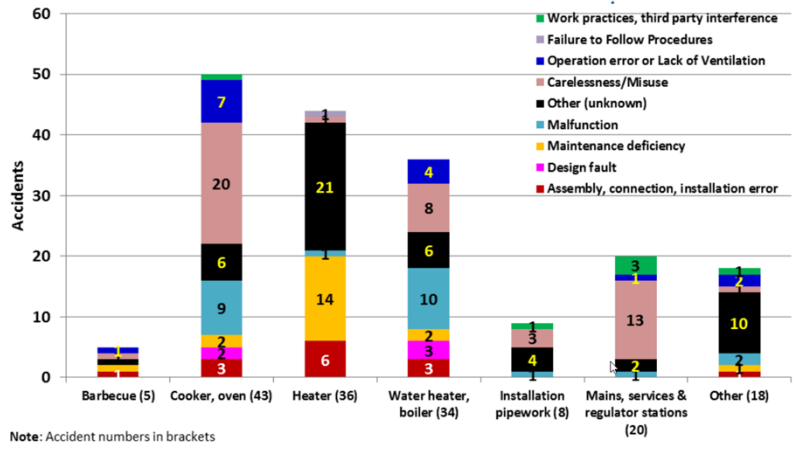
7

Accidents - causes of hospitalization Australia 2019-20



8

Natural gas accidents requiring medical treatment - 10-year totals, Aus + NZ

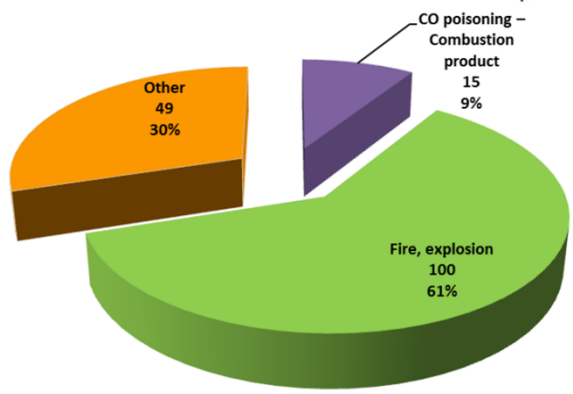


Note: Accident numbers in brackets

GTRC: Serious Gas Accident Report, 2010-20



Causes of injury - 10-year totals, Aus + NZ



GTRC: Serious Gas Accident Report, 2010-20



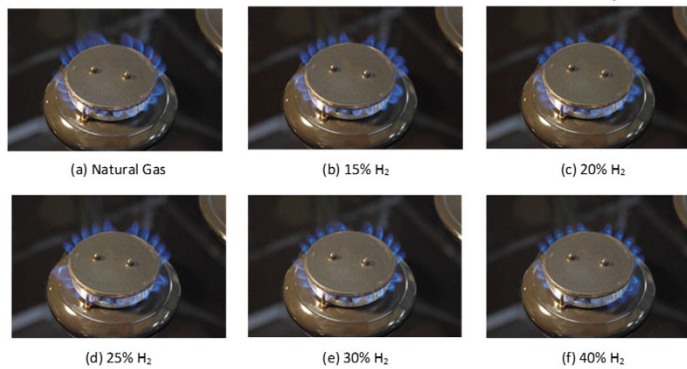
Differences with Hydrogen

Parameter	Hydrogen (H ₂)	Methane (CH ₄)
Relative density**	0.07	0.55
Laminar flame speed, cm/s	290	43.4
Flammability limits (lean-rich), vol%	4.0–75	5.0–15.0
Minimum ignition energy, 10 ⁻⁴ J	0.2	4.7
Air-fuel ratio	2.38	9.52



11

Flame appearance of hydrogen / natural gas blends



12

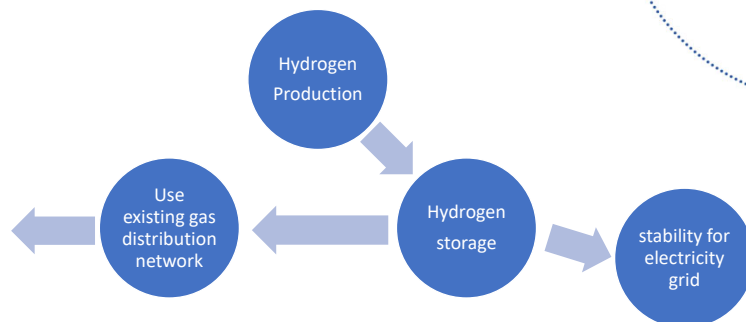
Blends of up to 20% Hydrogen into natural gas

- Tested 27 new and old appliances at certified labs and University of Adelaide
- water heaters, space heaters, cookers, deep fryer and pasta cooker, BBQ, pool heater
- No noticeable change to performance, amenity, safety, emissions (CO and NO₂)
- No changes required
- Flame safeguard operates as designed
- Billing still accurate
- 2 - 10 vol% network demonstrations underway
- A chance to be a part of the transition by promoting a market for hydrogen which helps drive down the cost of production



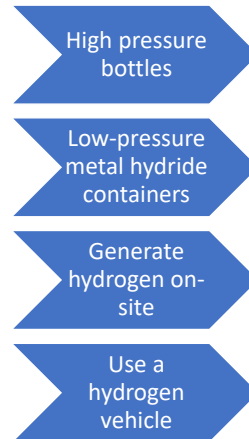
13

100% Hydrogen supply



14

100% Hydrogen domestic supply – fringe possibilities



15

100% H₂ appliances are under development

Cooker burner

1. Standards being updated (for safety, testing and installation)
2. Demonstrations - AGIG Hydrogen home Melbourne
3. Materials / piping / instrumentation
4. Appliances not commercial yet



16



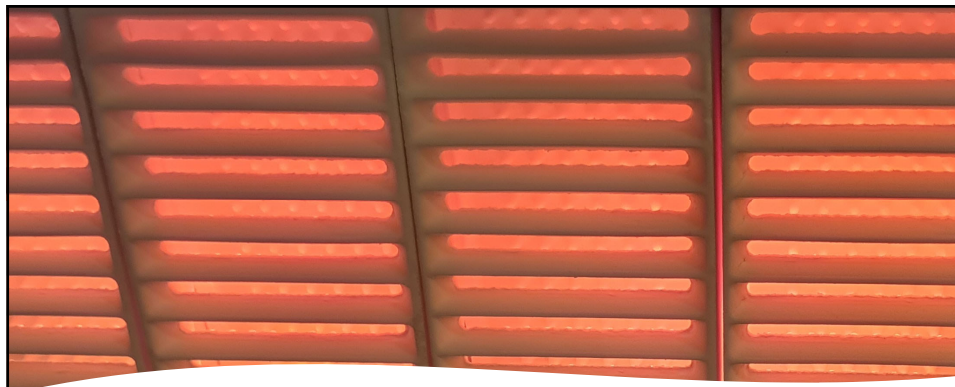
16

100% Hydrogen appliance safety

- Odorant
- Flame detector
- Zero CO emissions
- NO₂ emissions
 - Catalytic burners
 - Non-catalytic burners



17



NO₂ emissions under investigation

- Burner design
- low temperature inside a burner or outside
- Many appliances are flued.
- There are no CO emissions (of-course)



18

100% Hydrogen appliance safety

Leakage from properly connected appliance:

AS/NZS 5263.0:2017 for gas appliances has an appliance leakage test using air at 1.5x normal operating pressure.

- Our results for 100% hydrogen ~ 2x the air rates but well below limit of 1 ml/min
- Too low for fire ignition or economic loss.



19

Explosions and fires theory

If despite all safety measures a leak occurs, e.g. broken inlet pipe, with 7mm hole

Hydrogen volumetric leak rate is higher than natural gas.

But similar time required before explosion in a room with poor ventilation

~ 2 hours



Figure 13: Photo of the Chamber View Explosion (CVE) test facility [18]



Source: M. Schiavetti and M. Carcassi. (2019). Inhomogeneous hydrogen deflagrations in the presence of obstacles in 25m³ enclosure, experimental results in International Conference on Hydrogen Safety, Adelaide, cited in Nikhil Hardy, (2021). Work Package 7: Hy4Heat Safety Assessment - Gas Ignition and Explosion Data Analysis. Department of Business Energy & Industrial Strategy. [Gas Dispersion Data analysis Report \(squarespace.com\)](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/98484/Gas_Dispersion_Data_analysis_Report_squarespace.com)

20

Hydrogen Safety – Explosion tests

Hy4Heat testing (UK)

- Deliberate ignition of gas in rooms at a concentration above the Lower Explosive Limit.
- Measure pressure impulse with time

Results

- ignition and vent locations
- Noise, pressure.
- No higher risk of injury
- Marginally higher explosion risk from hydrogen leaks

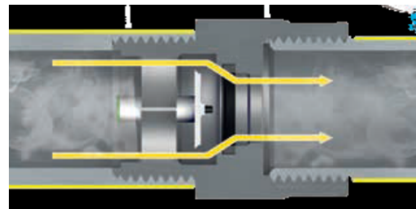


21

100% Hydrogen safety

Hy4Heat (U.K.) - Quantitative Risk assessments (QRA)

- help decide safety measures
- ALARP
- Use two excess flow valves to limit flow into the house can reduce risks from hydrogen down to same as NG. (TECO GST brand shown)
- Small leaks don't spontaneously ignite



22

Safety measures for 100% hydrogen

As for natural gas

- Use odorant
- Adequate ventilation
- If there is a domestic (low pressure) leak it will not ignite unless there is an ignition source
- **Flames are visible (orange/yellow for hydrogen)**
- Burner design for low NO₂



Not done (or not always done) for natural gas

- Flame failure device on all appliances
- Excess flow valves
- Hydrogen leak detection alarms
- Piping and instrumentation audit and leak test



23

100% hydrogen costs in the home

- Traditionally gas has been cheaper than electricity.
- Hydrogen appliances will be similar cost to gas appliances
- Cheaper – retrofit gas appliances with hydrogen burners and flame detectors (~20% of appliance cost)
- Cost of Hydrogen, e.g. IEA, \$USD 3- 8 in future



Global Hydrogen Review
2021

- Hydrogen appliances and distribution can compete with electric



24



Enabling the decarbonisation of Australia's energy networks

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



Australian Government
Department of Industry, Science,
Energy and Resources

Business
Cooperative Research
Centres Program



PRESENTATION TO COMMERCIAL AND INDUSTRIAL USERS



Hydrogen - commercial appliances and industrial applications

Outline:

- Gas appliances , burners, BMS
- Hazards, accidents, injuries
- Hydrogen properties
- Blends up to 20 vol% hydrogen
- Hydrogen supply
- 100% Hydrogen appliances, safety, cost

1

Industrial and commercial gas uses

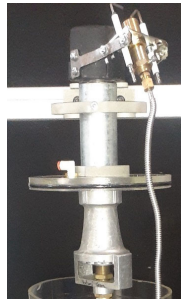
- Space heating – ducted (indirect), direct fired
- Water heating – Multiple Type A, condensing
- Steam (boilers)
- Spray booths – Infrared and convective heating
- Ovens – wide range of temperatures food, enamelling etc
- Furnaces – steel heat treating etc
- Kilns – direct heating from flame to reactants / product
- Infrared dryers (e.g. paper industry augmenting drum dryers)



2

Current gas burners - examples

Atmospheric partial pre-mixing
Pizza oven, lauder burner



3

Current gas burners

Furnaces, kilns, ovens etc

- Non-premixed
- Partial premixed
- Nozzle-mix
- Lean pre-mixed (extra air, lower Nox)
- Heat recovery (recuperative, regenerative)

Type B Appliances

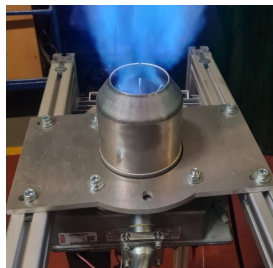
- gas hot water, boilers
- gas space heating
- radiant heating
- Burners for process heating



4

Current gas burners - examples

Package burner
Nozzle mix

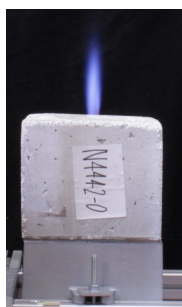


5

Current gas burners - examples

High velocity burner

- Multiple burners
- Pulsed
- Metals heat treatment with uniform temperatures



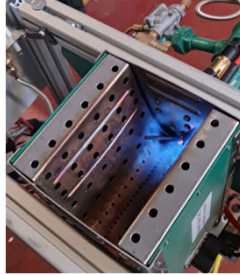
6

Current gas burners - examples

Air heat burner

High excess air

In a duct with more air, to produce hot air for drying etc.



7

Current gas burners - examples

Torches, direct heating

(Source: Siemens air-fuel ratio controller brochure)

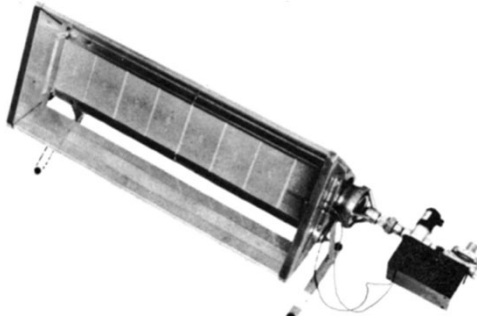


8



Current gas burners - examples

Space heating

Radiant panel
Source: Tolleys Industrial and commercial gas installations


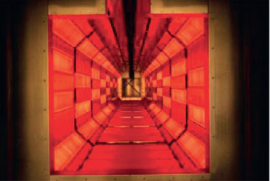


Radiant tube
Source: Celmecc

9

Current gas burners - examples

Catalytic Infrared dryers, heaters

Fuel + oxygen react at low temperature


- Flameless
- Efficient

Used with LPG, natural gas

- avoids NOx

Hydrogen catalytic heaters being developed, e.g. cookers

Source: Catalytic combustion of hydrogen for heat production. J. Saint-Just, S. Etemad

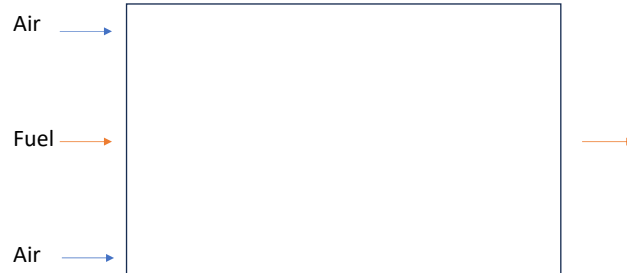


10

Current gas burners - examples

Flameless oxidation
Delay fuel / air mixing

Low temperature and low NO_x



11

Burner management systems for safety

- 30 second pre-purge with air
- Fuel / air ratio controller
- Pilot Ignition control
- Pilot flame proving
- Main flame detection and shutoff valves
- Pressure, Temperature, CO sensing and shutdown

Type B appliance approvals on case-by-case basis using Standards

AS 3814 Industrial and commercial gas-fired appliances

AS 1375 Industrial fuel-fired appliances



12

Current gas appliances - Hazards

Hazards from accidental misuse or rare failures:

HAZARD	Cause	Protective measures
Unignited gas, potential explosion or fire, smoke	Leak Appliance ignition failure External ignition source	Installation and ventilation to Standards Flame detection Odorant Smoke, CO alarms



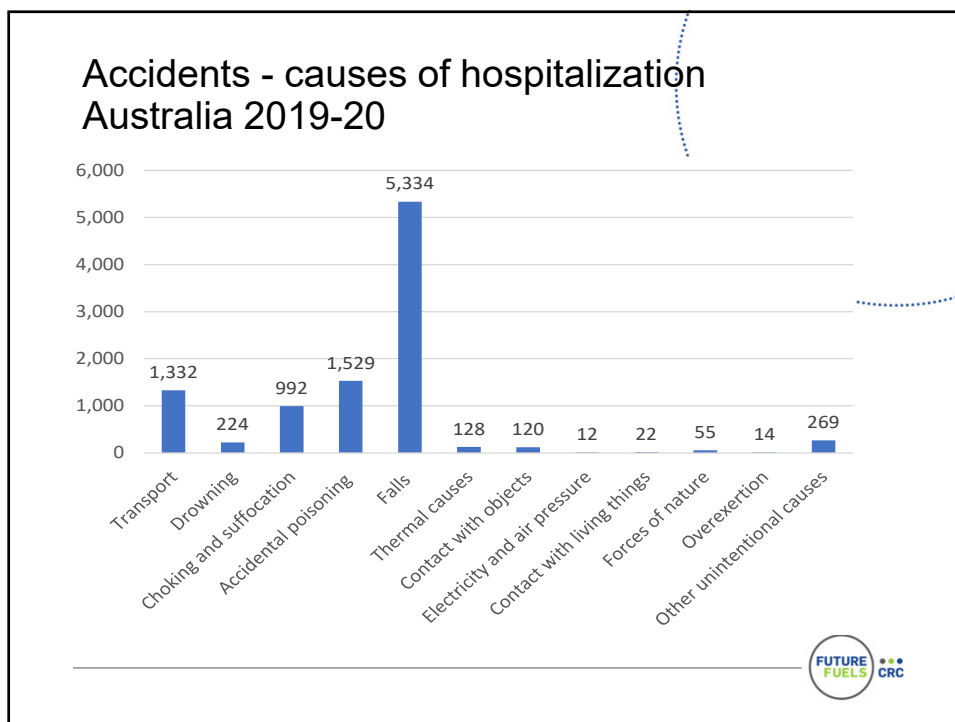
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Current gas appliances - Hazards

HAZARD	Cause	Protective measures
Burns	flame or hot surfaces	Flame visibility Insulation Correct operation
Carbon monoxide	Poor combustion, quenching	Design and test to standards Proper operation and ventilation CO alarm
Nitrogen dioxide	High flame temperature	Design and test to standards. Proper ventilation.



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Differences with Hydrogen

Parameter	Hydrogen (H ₂)	Methane (CH ₄)
Relative density**	0.07	0.55
Laminar flame speed, cm/s	290	43.4
Flammability limits (lean-rich), vol%	4.0–75	5.0–15.0
Minimum ignition energy, 10 ⁻⁴ J	0.2	4.7
Air-fuel ratio	2.38	9.52

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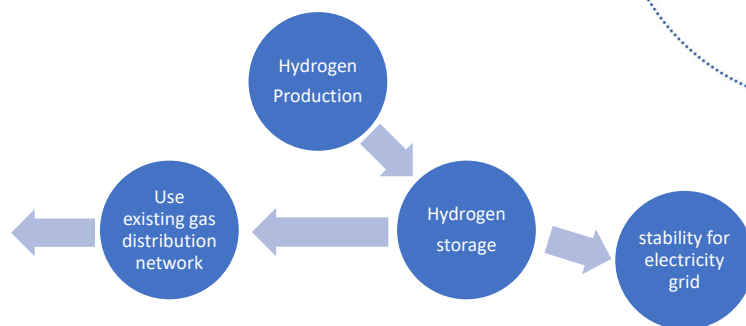
Blends of up to 20% Hydrogen into natural gas

- Tested 27 new and old appliances at certified labs and University of Adelaide
- water heaters, space heaters, cookers, deep fryer and pasta cooker, BBQ, pool heater
- No noticeable change to performance, amenity, safety, emissions (CO and NO₂)
- No changes required
- Flame safeguard operates as designed
- Billing still accurate
- 2 - 10 vol% network demonstrations underway
- A chance to be a part of the transition by promoting a market for hydrogen which helps drive down the cost of production
- **Now testing Type B burners with hydrogen and measuring heat transfer and NOx**



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100% Hydrogen supply



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100% Hydrogen industrial supply – fringe possibilities

- High pressure tankers
- Low-pressure metal hydride containers
- Generate hydrogen on-site

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100% hydrogen:

- Lean premixed burners
- Catalytic burner designs

} Low temperature

Aim for low NO_x emissions

- Adjust traditional burners + Flue gas recirculation or staging
- no CO emissions

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100% Hydrogen appliance safety

- Leak checks
- Hydrogen leak detectors
- Odorant
- Flame detection
- Zero CO emissions



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Explosions and fires theory

If despite all safety measures a leak occurs, e.g. broken inlet pipe, low pressure, with 7mm hole

Hydrogen volumetric leak rate is higher than natural gas.

But similar time required before explosion in a room with poor ventilation

~ 2 hours



Figure 13: Photo of the Chamber View Explosion (CVE) test facility [18]



Source: M. Schiavetti and M. Carcassi. (2019). Inhomogeneous hydrogen deflagrations in the presence of obstacles in 25m³ enclosure, experimental results in International Conference on Hydrogen Safety, Adelaide, cited in Nikhil Hardy, (2021). Work Package 7: Hy4Heat Safety Assessment - Gas Ignition and Explosion Data Analysis. Department of Business Energy & Industrial Strategy. [Gas Dispersion Data analysis Report \(squarespace.com\)](https://www.squarespace.com)

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Hydrogen Safety – Explosion tests

Hy4Heat testing (UK)

- Deliberate ignition of gas in rooms at a concentration above the Lower Explosive Limit.
- Measure pressure impulse with time

Results

- ignition and vent locations
- Noise, pressure.
- No higher risk of injury
- Marginally higher explosion risk from hydrogen leaks

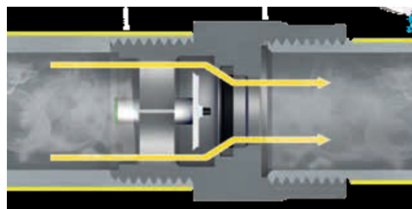


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100% Hydrogen safety

Hy4Heat (U.K.) - Quantitative Risk assessments (QRA)

- help decide safety measures
- ALARP
- Use two excess flow valves to limit flow into buildings can reduce risks from hydrogen down to same as NG. (TECO GST brand shown)
- (similar requirements likely for industry)
- Small leaks don't spontaneously ignite



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Safety measures for 100% hydrogen

As for natural gas

- Use odorant
- Adequate ventilation
- low pressure leaks inside buildings will not ignite unless there is an ignition source
- Flames are visible (orange/yellow for hydrogen – less so outdoors and at higher pressure)
- Burner design for low NO₂



Not done (or not always done) for natural gas

- Flame failure device on all appliances
- [Excess flow valves](#)
- [Hydrogen leak detection alarms](#)
- Piping and instrumentation audit and leak test



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100% hydrogen costs

- Traditionally gas has been cheaper than electricity.
- Hydrogen appliances will be similar cost to gas appliances
- Cheaper – retrofit gas appliances with hydrogen burners and flame detectors (~20% of appliance cost)
- Cost of Hydrogen, e.g. IEA, \$USD 3- 8 in future



**Global Hydrogen Review
2021**

- ANU study - \$ 2/kg
- Hydrogen appliances, burners and distribution may become viable in next decade



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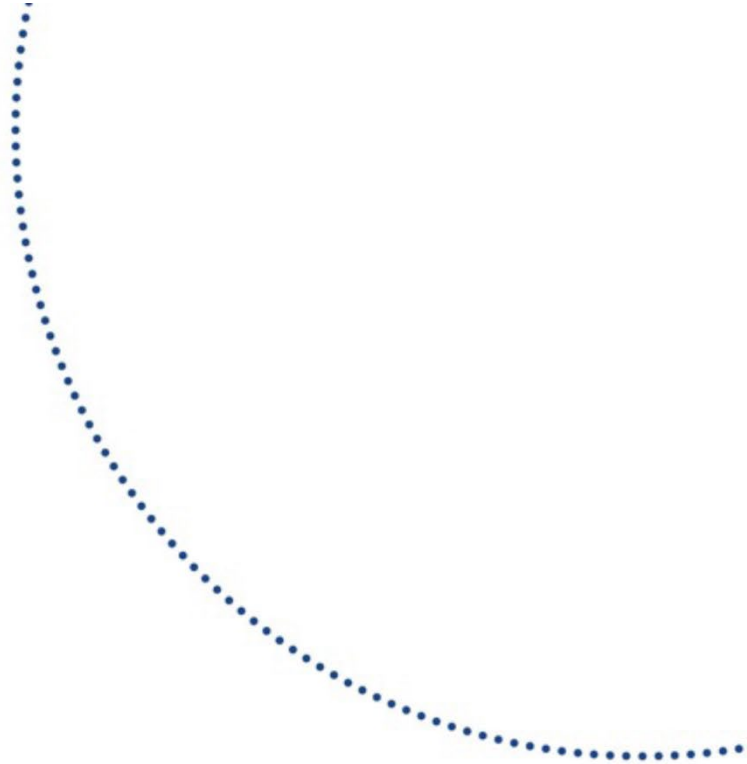
Enabling the decarbonisation of Australia's energy networks

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