MACQUARIE University

Sustainable Energy Research Centre (SERC)

CHALLENGES IN HYDROGEN STORAGE, TRANSMISSION, AND APPLICATION - SAFETY ASPECTS.
25 NOVEMBER 2020

Photo by American Public Power Association on Unsplash

AGENDA

1. Welcome
2. The role of hydrogen in local governments
3. MQSERC overview
4. Introduction
5. Panel – Challenges in hydrogen safety - storage, transmission, and application
6. Collaborative workshop:
    1. Critical industry issues in hydrogen safety
    2. Critical enterprise issues in hydrogen safety
    3. Barriers to reliability and safety
    4. Priority areas for research partnership
7. Lunch
8. Close

MACQUARIE University
SYDNEY·AUSTRALIA

Welcome

PROFESSOR MAGNUS NYDÉN

MACQUARIE University

Acknowledgment of Country

"I acknowledge the traditional custodians of the Macquarie University land, the Wattamattagal clan of the Darug nation, whose cultures and customs have nurtured, and continue to nurture, this land, since the Dreamtime. We pay our respects to Elders past, present and future."

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CHALLENGES IN HYDROGEN STORAGE, TRANSMISSION AND APPLICATION – SAFETY ASPECTS

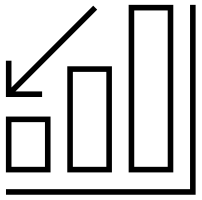
The Third Industrial Revolution

PROFESSOR MAGNUS NYDÉN
EXECUTIVE DEAN,
FACULTY OF SCIENCE AND ENGINEERING

25 November 2020

The need for a new economic era

- 20 years of low GDP
- Many years of low productivity



The fossil era has reached maximum productivity.*

* Jeremy Rifkin, “A new Green Deal for Europe”, DLD Munich, Jan 18-20, 2020

Previous industrial revolutions

1st industrial revolution, Britain 1760-1840:

- Fast printing, telegraph
- Coal for steam power
- Railway and trains (coal powered steam engines)

2nd industrial revolution, US 1870-1914:

- Telephone
- Texas oil for electric power
- Henry Ford (petrol powered combustion engine)

20% aggregate efficiency

* Jeremy Rifkin, “A new Green Deal for Europe”, DLD Munich, Jan 18-20, 2020

Fundamentals

1.	2.	3.
New COMMUNICATION system	New ENERGY system	New MOBILITY system for transport and logistics

Increased productivity

Increased GDP

* Jeremy Rifkin, “A new Green Deal for Europe”, DLD Munich, Jan 18-20, 2020

3rd Industrial revolution?

1.	2.	3.
IoT, sensors (+ ML and AI)	Renewable energy – wind and solar	EV's and H_2

All decentralised and digitised – 60% aggregate efficiency

HYDROGEN IS AT THE HEART OF THE NEW ECONOMY

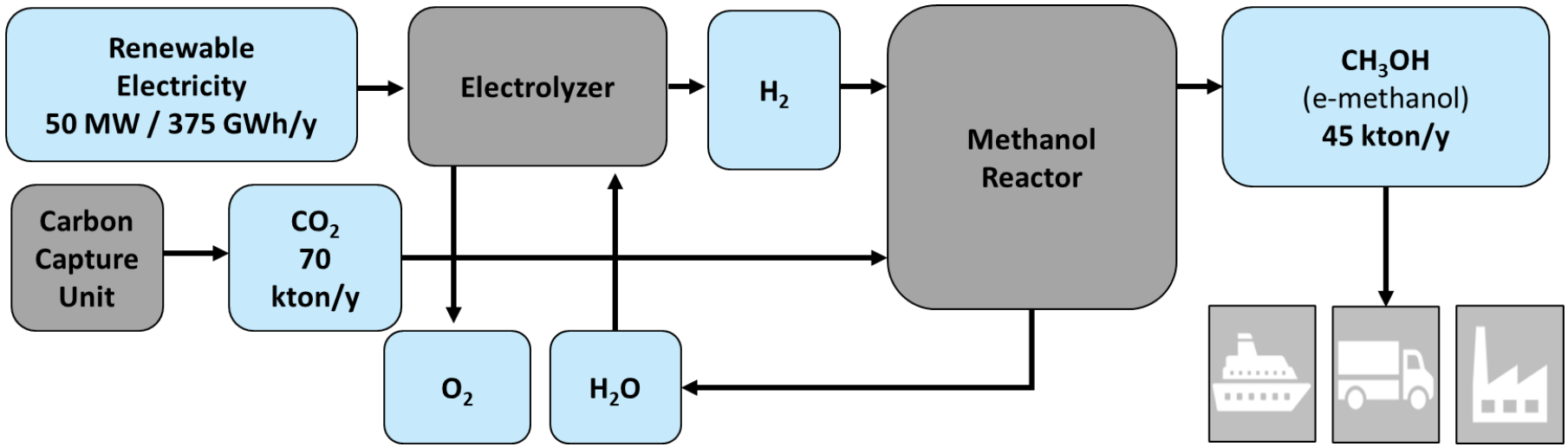
* Jeremy Rifkin, "A new Green Deal for Europe", DLD Munich, Jan 18-20, 2020

A former life experience

Former CTO
and
Public Policy
Director

www.liquidwind.se

Converting Renewable Electricity to e-fuel



MACQUARIE
University

Thank you

The role of hydrogen in local governments

MAYOR JEROME LAXALE

(CITY OF RYDE)

MQ SERC Overview

PROFESSOR DARREN BAGNALL

Sustainable Energy Research Centre (SERC)

VISION

The Sustainable Energy Research Centre was established to drive the renewable energy transition by combining the expertise of researchers, industry, and government to develop innovative solutions for next generation clean energy conversion, energy storage and energy distribution technologies that are cost effective, reliable and safe.

Our research experts specialise in the production and utilisation of sustainable energy sources such as hydrogen, photovoltaic (PV) materials and solar energy systems as well as energy integration and energy economic solutions.

W: mq.edu.au/research/research-centres-groups-and-facilities/secure-planet/centres/sustainable-energy-research-centre

@MQ_SERC

linkedin.com/company/sustainable-energy-research-centre

Sustainable Energy Research Centre (SERC)

CORE RESEARCH AREAS

Photovoltaics and Solar Energy

- development of photovoltaic materials for next generation high efficiency solar cells
- development of device fabrication technologies to reduce the cost of power generation

Hydrogen

Production and Utilisation

- bio-hydrogen production to increase the rate and yield of hydrogen production with minimal by-products
- Chemical production of hydrogen using a sustainable chemical looping process

Application and Safety

- provide scientific and technical knowledge in understanding the safety aspects related with hydrogen energy applications
- risk analysis and consequence modelling regarding hydrogen applications

Grid Integration

- Energy management and distribution for commercial and residential systems, micro grid and grid integration
- integration of electrical vehicles into the grid for charging and supply

Energy Economics

- Financial innovation strategies to stabilise energy markets moving from fossil-fuel fired power generation to a renewable energy model

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Introductions

LARA MOROKO

Industry Panel

WODEK JAKUBIK – CORE GAS

BILLY CHAN – BOC

ROBERT NICHOLSON – PITT&SHERRY

Hydrogen Gold Rush

Wodek Jakubik, Coregas

Coregas Hydrogen

- The largest merchant Hydrogen Plant
- Expertise: production, compression, distribution and storage
- Liquid hydrogen experience from HESC project
- Currently “grey” hydrogen, possible “green” and “blue” hydrogen in 2021
- Tube trailers fleet 300 kg @ 200 bar

Hydrogen market

69 million tonnes of dedicated ‘pure’ hydrogen plus an additional ~48 million tonnes per year of hydrogen as produced as a bi-product of other processes

Australia produced about 0.5 million tonnes of hydrogen in 2019, mostly to produce ammonia

Chart 1: Hydrogen Production by Process Fuel

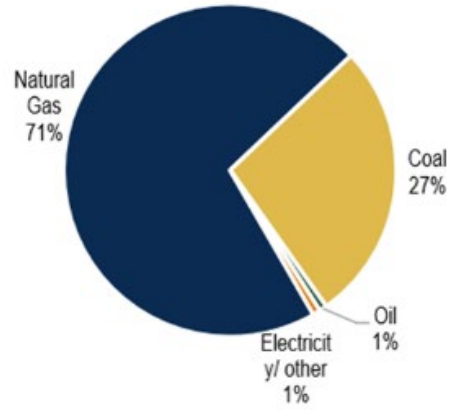
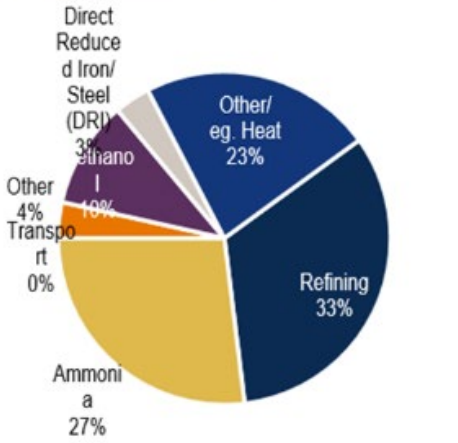


Chart 2: Hydrogen Use by Sector



Bloomberg estimates that hydrogen could meet up to 24% of the world’s energy needs by 2050 (in a 1.5-degree scenario), requiring 696 mil tonnes of hydrogen per year and annual sales of $700 billion (excluding end-use equipment).

Australian hydrogen roadmap

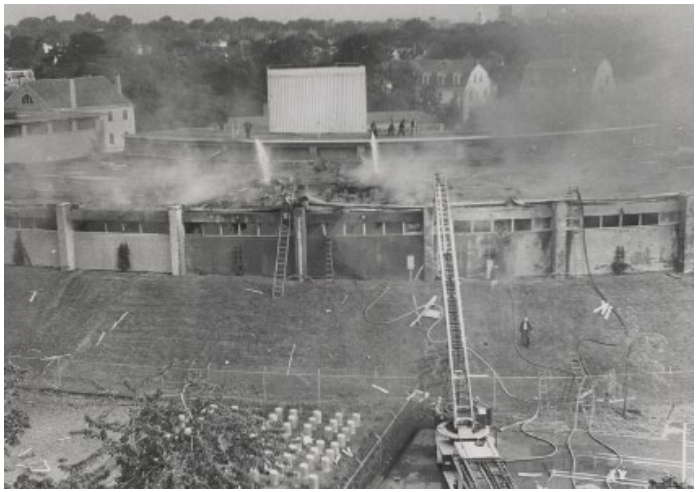
- **Catching up** with California, Europe, China, Korea and Japan 
- Government funding: 
  - Export
  - Natural gas grid injection
  - Ammonia production
  - Remote microgrids
  - Mining
- Carbon price, emission reduction targets, tax benefits 
- Expertise, experience and standards 

The perception of hydrogen safety

Hydrogen was commonly used to light and heat houses during the hundred years between 1850 and 1950. Coal gas (or city gas) was up to 50 percent hydrogen.

Until:

- Hindenburg disaster at Lakehurst New Jersey in 1937
- Cambridge Electron Accelerator in Cambridge Massachusetts in 1965



Safety hazards

Potential Safety Hazard	H_2	CH_4	C_3H_8
Large liquid to gas expansion ratio	Yes	Yes	Yes
Cryogenic embrittlement of materials	Yes	Yes	Sometimes
Freezing of body parts (human)	Yes	Yes	Maybe
Flammability and chemical explosion	Yes	Yes	Yes
Chemical embrittlement of materials	Yes	No	No
Oxygen enrichment due to temperature	Yes	No	No
Asphyxiation (oxygen deprivation)	Yes	Yes	Yes
Is the gas heavier than 300 K air?	No	Sometimes	Always

Source: Michael A. Green Lawrence Berkeley National Laboratory

First step: New hydrogen related Australian Standards 2020

- **AS 16110.1:2020**, Hydrogen generators using fuel processing technologies, Part 1: Safety
  Small scale generation (nominally <850 kg/day) using natural gas for a direct source or gas network, or biogas feed to generate H2 for use.
- **AS ISO 16110.2:2020**, Hydrogen generators using fuel processing technologies, Part 2: Test methods for performance
- **AS ISO 14687:2020**, Hydrogen fuel quality – Product specification
- **AS 22734:2020**, Hydrogen generators using water electrolysis – Industrial, commercial, and residential applications
- **SA TS 19883:2020**, Safety of pressure swing adsorption systems for hydrogen separation and purification
- **AS ISO 16111:2020**, Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride
- **AS ISO 19881:2020**, Gaseous hydrogen – Land vehicle fuel container
- **AS 19880.3:2020**, Gaseous hydrogen – Fueling stations, Part 3: Valves

Hydrogen Storage – A Snapshot of Past, Now and Then

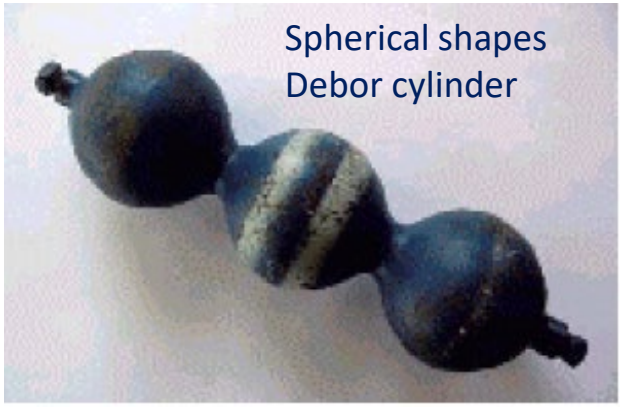
Sustainable Energy Research Centre, Macquarie University

Billy Chan, Senior Engineer – Gas Processes & Cylinders
BOC, A member of Linde Group
Chair of ME-2-4 (Gas Cylinder Operations)
Convenor of ME-93-10 (H2 Production, Handling and Storage)

SERC Workshop 25 November 2020

Gas Storage – In the Beginning

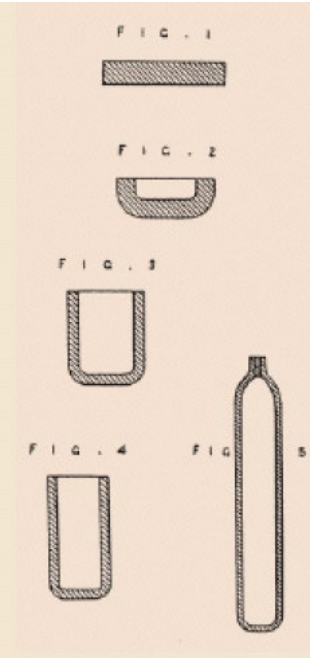
1850s: Brins Brothers (founder of BOC) used to store O2 produced from the thermal decomposition of BaO2



Gas storage design aspects

- Safety
- Convenience
- Affordability

1886: Lane & Taunton developed the first steel cylinders
British Patent No 12371



1891: Ehrhardt adapted the plate route by using a red block of steel (billet) which was pierced to form a thick-wall cup. The cup was then hot drawn to final dimension.

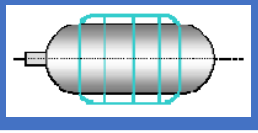
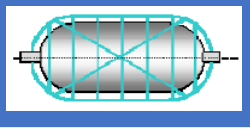
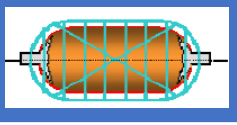
1892: Production from plates and billets was followed by cylinders made from tube, as a by-product of the invention in Germany by Max and Reinhard Mannesmann.

1910s: Only cylinders with convex (to atmosphere) base were produced. Finally the concept of concave based as an aid to stability/ease of transport and use was incorporated into the cylinder.

2020: BOC Aus. & NZ operate a fleet of 2.5 million high-pressure gas cylinders. BOC operates numerous H2 tube trailer fleet and on-site production.

Gas Storage – Over A Century of Experience

BOC
A Member of The Linde Group

Gas Cylinders (receptacle)	Type I 	Type II 	Type III 	Type IV 	Type V… 2050? (Type XCIX?)
Refillable structure for pressure retaining GH2	Gas cylinder (storage) made of metal structure (welded and seamless)	Made of a metallic liner hoop wrapped with a fibber-resin composite	Made of a metallic liner hoop wrapped with a fibber-resin composite	Made of a polymer liner fully-wrapped with a fiber-resin composite	2020: Birth of liner-less Q: What will be H2 storage in future?
Design standards examples (ISO, GTR)	ISO 9809-1; ISO 7688; ISO 11120; ISO 19881	ISO 11119-1 ISO/TS 13086-3	ISO 11119-2	ISO 11119-3 UN GTR #13; ISO 16111	Q: How do we build on the success
Gas membrane	Metallic	Metallic	Metallic	Polymer, metal boss	Q: Advance material?
Construction ISO 11114 Part 1, 2 & 4	Steel – C-Mn, Cr-Mo, AA6XXXX, AA7XXXX SS	Metal and fibre (S2 glass, aramid, carbon)	Metal and fibre (aramid, carbon)	Polymer and carbon fibre	Q: CFD to predict performance? Delamination control? Connection integrity?
Service life	Non-limited	Non-limited	Limited	Limited	Q: Risk modelling MTBF?
Integrity testing	Hydrostatic testing, UT (ISO6406), AET (ISO16148)	Hydro-test, MAE(?) ISO 11623	Hydro-test, MAE(?) ISO 11623	Hydro-test, MAE(?) ISO 11623	Q: Advance NDT integrity inspection methods? Overall storage system integrity assessment?

GH_2 Storage Examples – Transportable and Static

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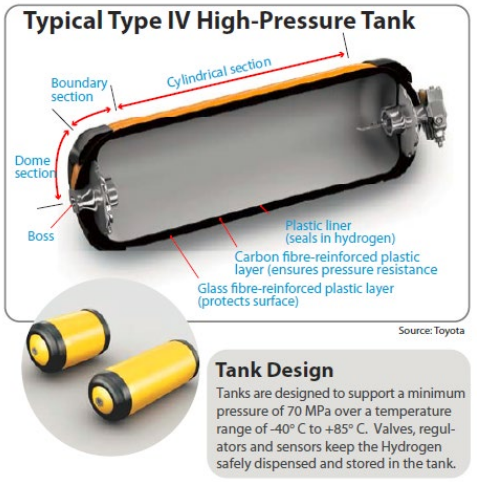
Typical modular on-site H_2 generation

Typical Type I, transportable tube trailer

Linde Ionic compressor

Typical 350bar Type III (e.g. Luxfer) onboard tanks

Typical modular Type IV, 950bar static storage (e.g. Hexagon)



Typical Type III tanks, bundle

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Specialist Knowledge.
Practical Solutions.

Hydrogen Storage, Transmission & Application

Robert Nicholson – Energy Market Leader
Date – 25 Nov 2020

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Practical Solutions.

We are an Australian-owned engineering and environmental consulting, advisory & project management business servicing the following markets:

- Energy
- Transport Infrastructure
- Mining
- Industrial & Manufacturing
- Civic & Utilities

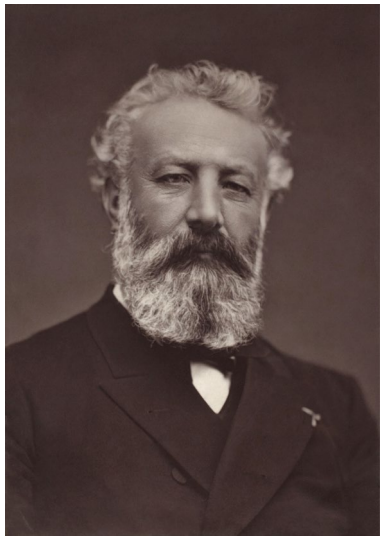
Est. 1963

250+ STAFF Australia-wide

$50M Annual Revenue

7 OFFICES

In 1874 Jules Verne wrote……



"…water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used

singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which

coal is not capable. Someday the coal-rooms of steamers and the tenders of locomotives will,

instead of coal, be stored with these two condensed gases, which will burn in the furnaces with

enormous calorific power."

The Mysterious Island

The opportunity

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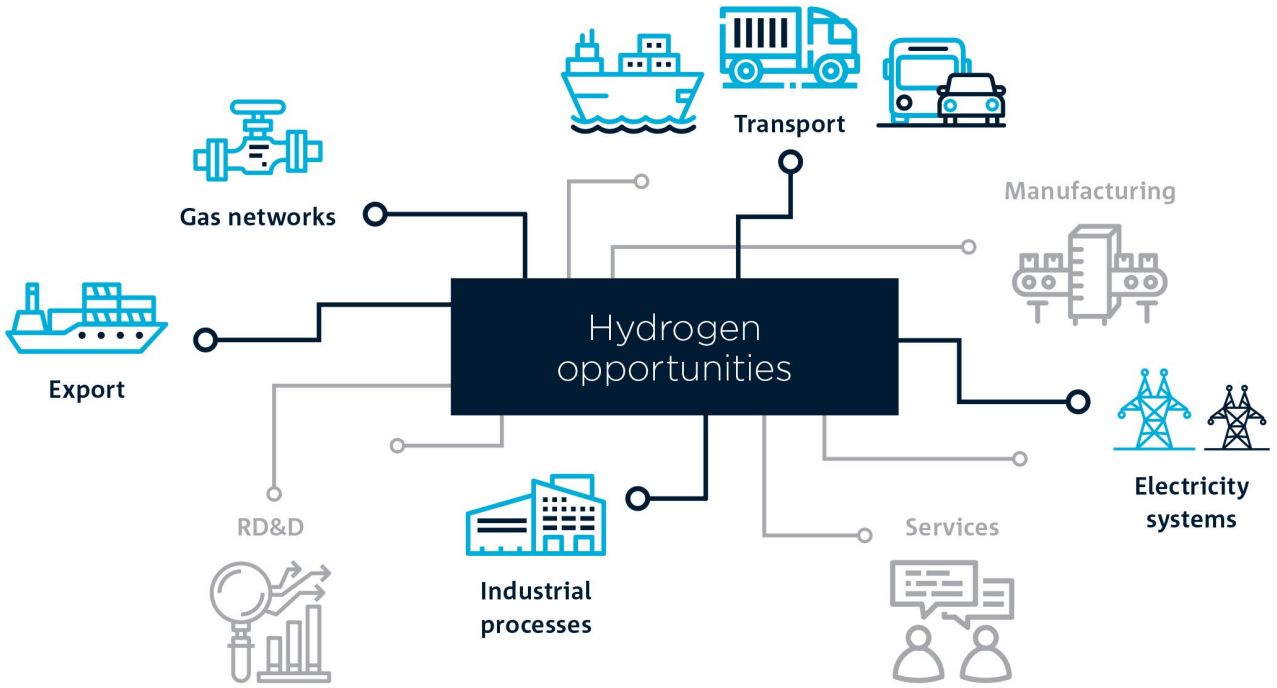
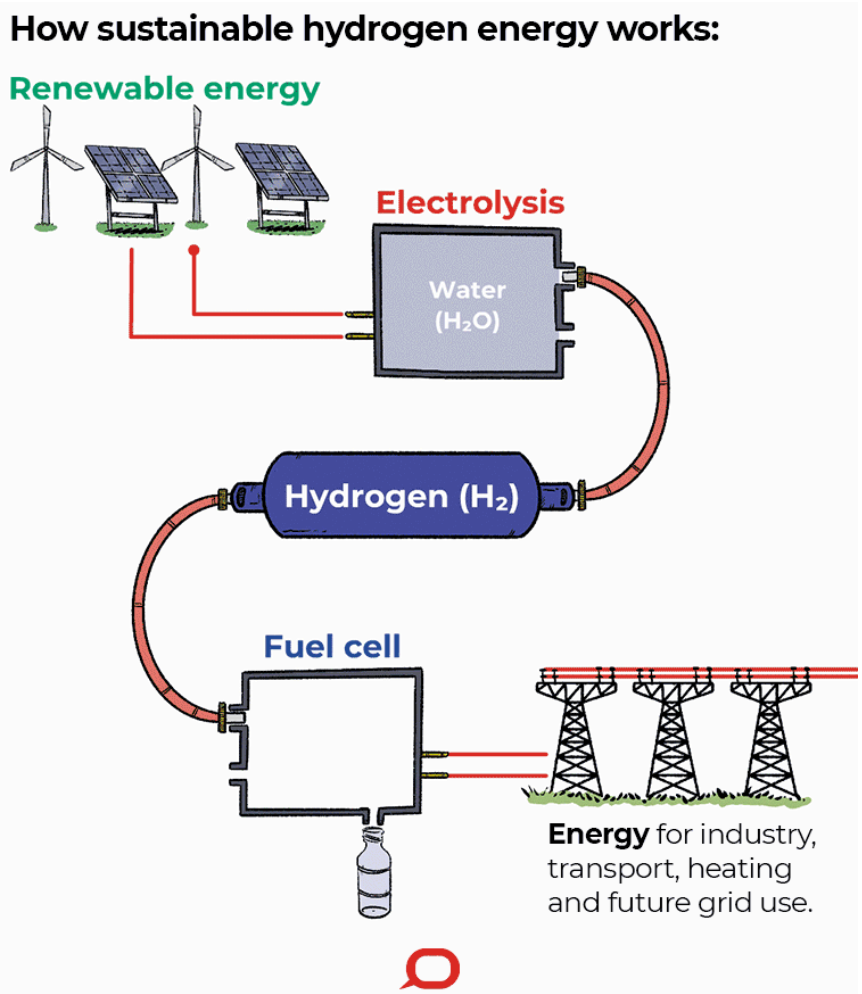
Deloitte estimates the Australian Hydrogen Industry will be worth A$26 Billion to Australian GDP by 2050 and could create 17,000 new jobs



https://www.csiro.au/en/News/News-releases/2019/Five-key-opportunities-identified-for-hydrogen-industry-growth



https://theconversation.com/145-years-after-jules-verne-dreamed-up-a-hydrogen-future-it-has-arrived-127701

Is it Safe?

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- Fuel cell electric buses (FCEB) have been operating in London for the past 10 years
- Tube trailer trucks carrying hydrogen drive up and down our highways in Australia every day
- The Mawson Station in Antarctica is powered by renewable hydrogen and transported in cylinders on a H_2 quad bike*
- It is used safely every day in ammonia production, petrochemical refineries, food, glass and chemicals manufacture
- Australia has an exemplary safety record.

hySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

*https://www.chiefscientist.gov.au/2019/09/speech-hydrogen-safety-at-scale

Storing Hydrogen

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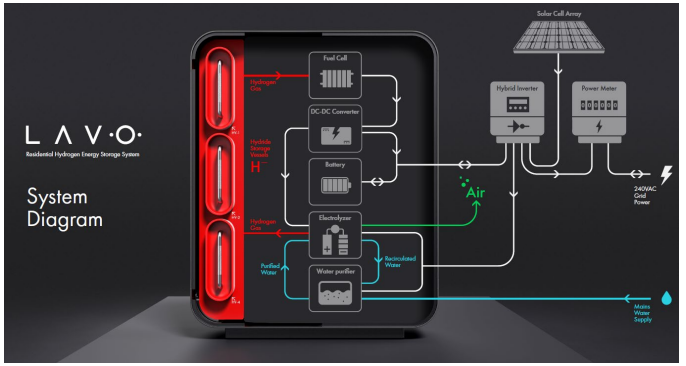
- Hydrogen liquifies at below 252.9 degrees (its boiling point)
- It can be stored as a liquid (cryogenic) or a gas under varying pressures
- In Australia it is common for hydrogen to be stored and transported in pressurised tubes (tube trailers)
- Its energy can be stored in gas pipelines mixing with LNG
- It can be stored in metal (Metal hydrides)
  - Griffith University
  - Lavo hydrogen battery storage (launched 20 Nov)



Applications in Australia

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- Heavy Vehicle Transport – Bus / Truck services
- Remote site diesel replacement (electricity generation)
- Gas injection into pipelines
- Replacing LNG in process heat
- Development of larger H_2 production projects – Methanol & ammonia production
- Export markets

What has pitt&sherry done

pitt&sherry

We've been involved in 7 projects and feasibility studies to date

- Design assistance of H2Xport pilot facility at QUT
- Producing Hydrogen from treated waste water - WWTP
- ESD – for highway refuelling stations
- Planning & Environmental approvals for major H2 developments

Engineering partner for ABEL Energy – 100MW green H2 and green methanol plant feasibility study in Tasmania (announced 17 Nov)

We're just scratching the surface. The opportunities for H_2 in Australia are enormous

“inspired thinking embracing the challenges of a changing world”

Thank you!

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Q&A – INDUSTRY PANEL

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BREAK (10 mins)

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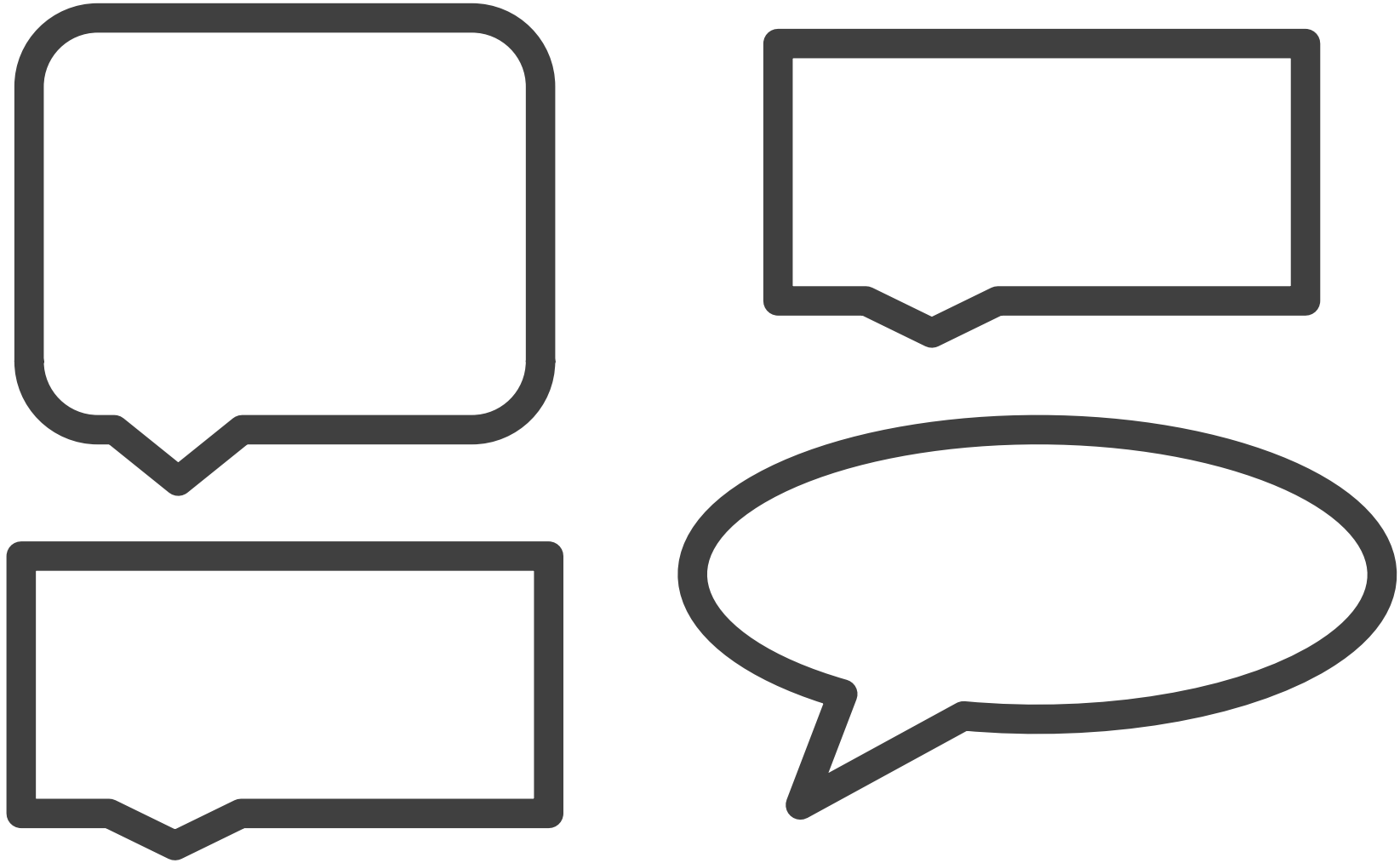
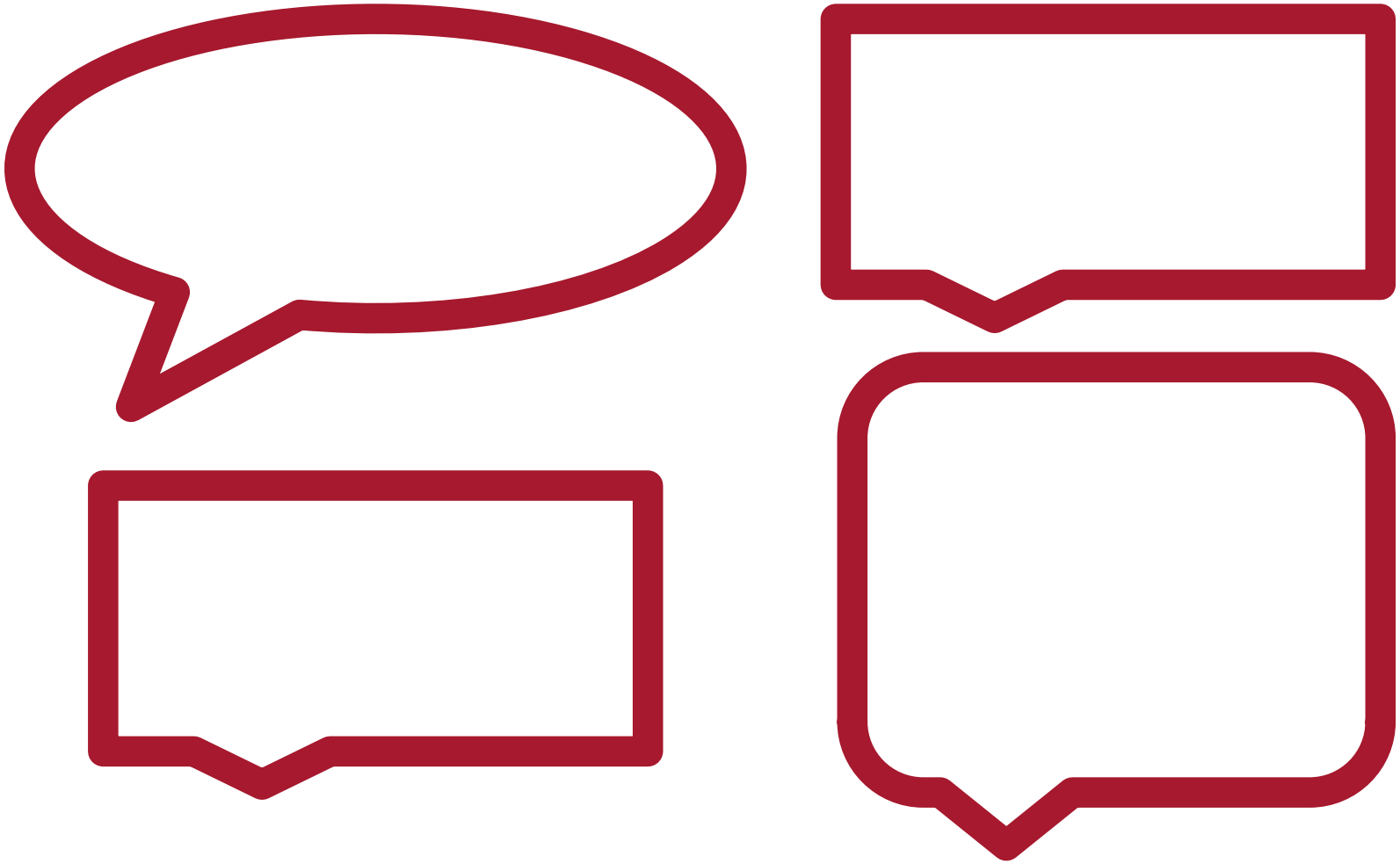
Collaborative Session

LARA MOROKO

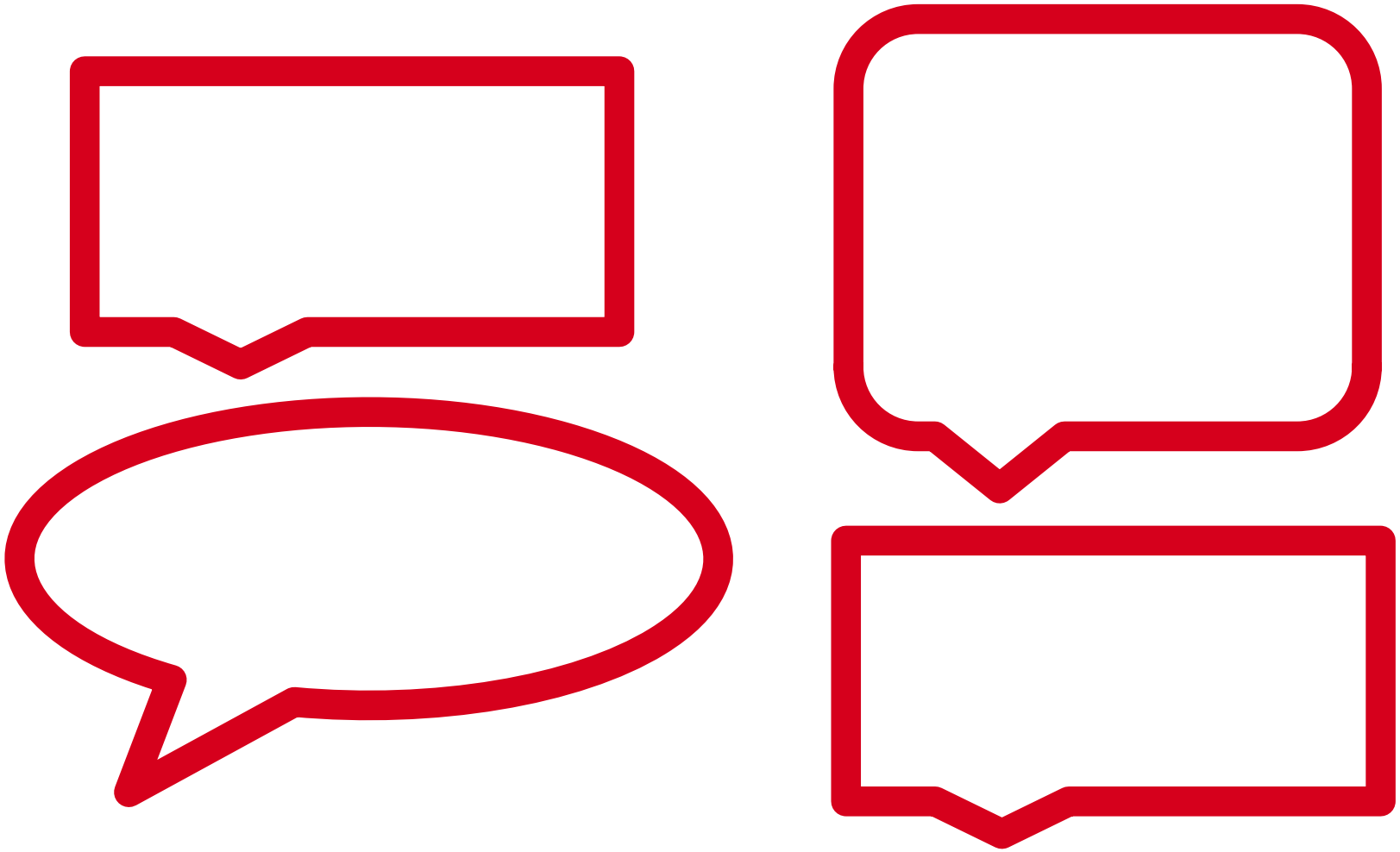
Top 3 issues critical to address for hydrogen safety in *your industry*



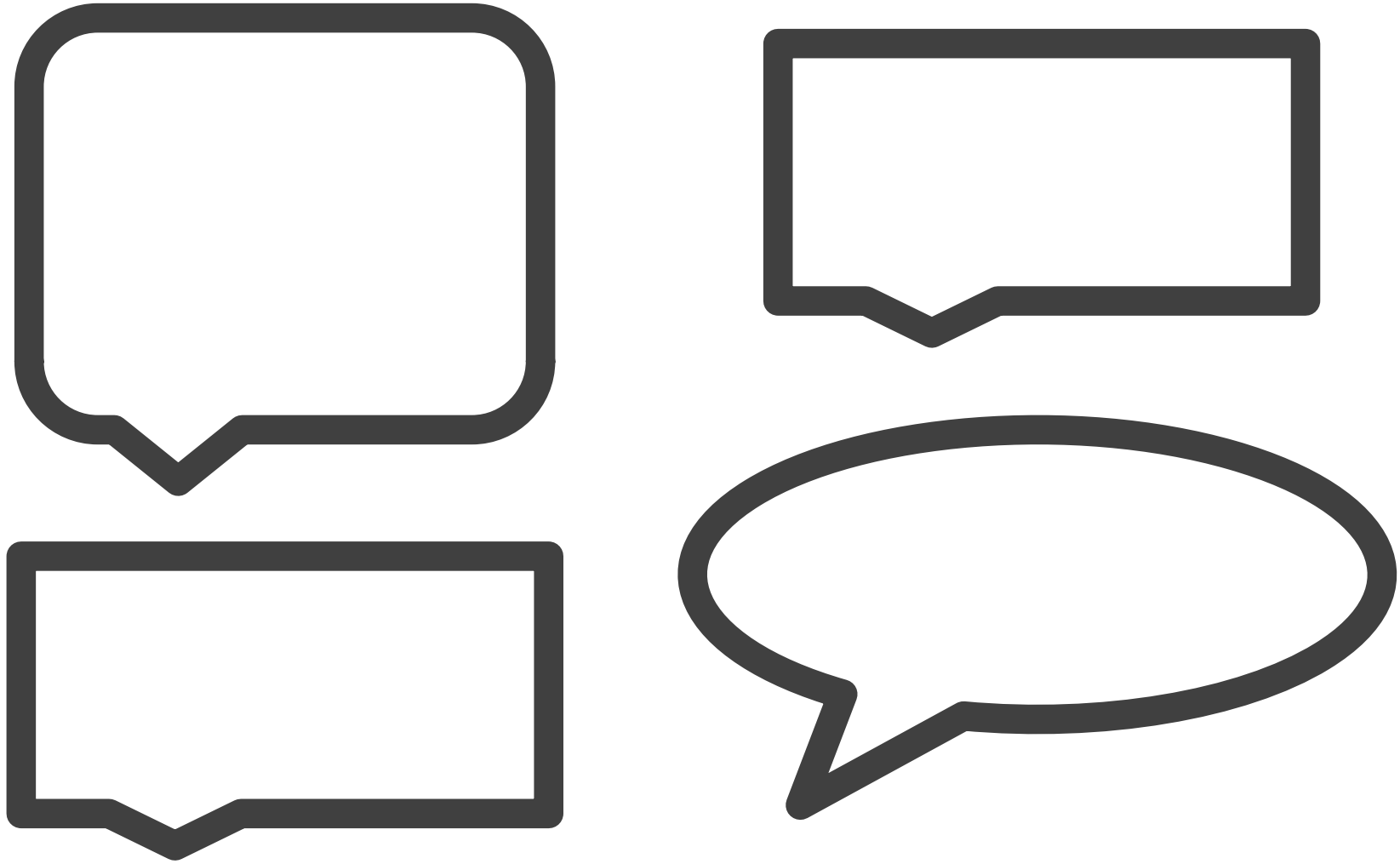
Top 3 issues critical to address for hydrogen safety in *your company*



Biggest barriers *to creating and ensuring trust* in hydrogen reliability and safety



Most important questions that researchers can *partner with industry to address*



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BREAK (30 mins)