Hydrogen Overview

Department of State Growth
Renewables Tasmania

Tasmanian Government

Presentation overview

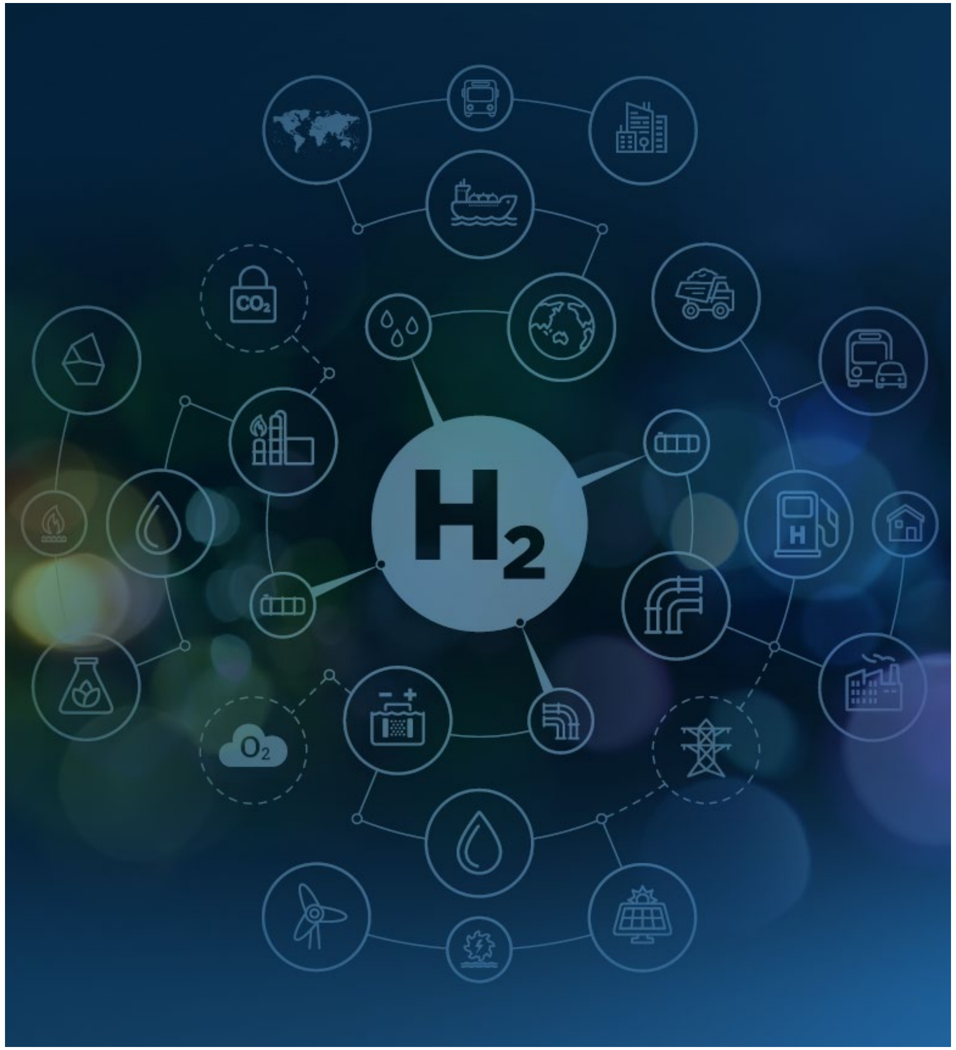
Presentation topics:

- Why hydrogen?
- Hydrogen properties
- Hydrogen production
- Hydrogen compression, storage & distribution
- Hydrogen utilisation
- Hydrogen export
- Challenges & opportunities
- TRHAP update
- Q&A

Top left: https://www.energiepark-mainz.de/en/project/pictures/

Bottom left: https://hydrogenenergysupplychain.com/5386-2/

Why hydrogen?



- Recognised as an important enabler for the transition to a decarbonised global energy system.
- No carbon emissions when produced from water using renewable energy.

Figure: Commonwealth of Australia, *Australia's National Hydrogen Strategy*

Hydrogen properties

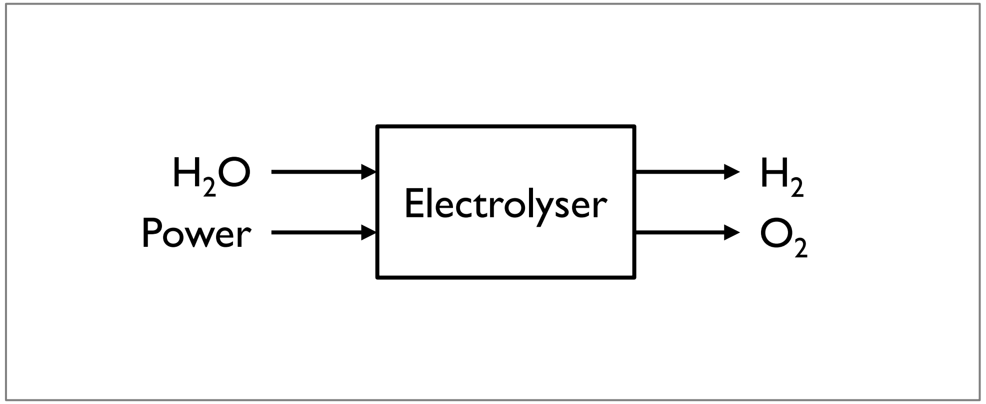
Hydrogen state	**Density [kg/m³]**
Gas @ 1 atm (1.013 bar), 15° C	0.0852
Gas @ 350 bar, 15° C	24.01
Gas @ 700 bar, 15° C	40.17
Liquid	70.85

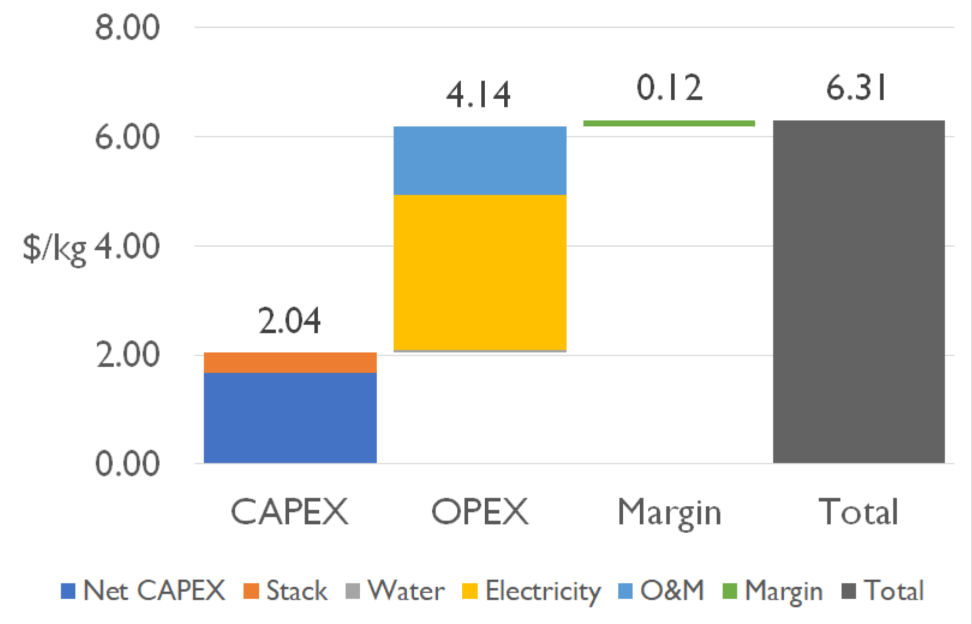
Source: https://webbook.nist.gov/chemistry/fluid/

- Hydrogen has a very low density at ambient conditions

  e.g. 5 kg = 58 m^3 (= 4.8 m diameter sphere) at 1 atm, 15° C
- Odourless, colourless, tasteless
- Non-toxic, although can cause asphyxiation if sufficient oxygen is displaced
- Hydrogen flame is nearly invisible to the human eye, and has low radiant heat (relative to natural gas)
- Wide flammability range, and low ignition energy (friction, static)
- Leakage considerations (small molecule)
- Disperses upwards very quickly
- Material compatibility considerations: hydrogen can cause embrittlement

Hydrogen production





- Currently hydrogen is predominantly produced from natural gas (SMR) and coal (gasification). Results in CO_2 emissions, unless carbon capture and storage is implemented.
- Renewable ('green') hydrogen can be produced by electrolysis using electricity from renewable generation. (Other options include: biological, and photo-electrochemical.)
- Electrolysis process uses electrical energy to split water into hydrogen and oxygen. (~ 9 L of de-ionised water per kgH_2)
- There are 3 main electrolysis cell types; alkaline, PEM, solid oxide. System efficiency depends on type and scale; ~50-70 kWh/kgH_2.
- Electricity cost and electrolyser utilisation are key drivers of hydrogen cost. 'H2 under 2' target is challenging.

Photo: https://www.energiepark-mainz.de/en/project/pictures/

Chart: example of hydrogen production cost breakdown; may vary by project/assumption set

Hydrogen compression, storage, and distribution

Hydrogen compression technologies:

- Reciprocating (piston, diaphragm), ionic liquid, electrochemical. (Note: metal hydride storage can provide a compression function.)

Hydrogen storage technologies:

- Compressed gas, liquid hydrogen, metal hydride, chemical storage.

Hydrogen distribution options:

- Pipeline (gas), road/rail (200/500 bar gas or LH2), ship (export).

Photo: FIBA

Hydrogen utilisation

Overview

Hydrogen has applications across many sectors and industries; agriculture, aquaculture, logistics, mining, passenger transport, etc.

Applications (main categories)

- Transport (mobility)
- Heating
- Chemical / Industrial processes
- Electricity generation

Also opportunities to use by-products; oxygen, and heat.

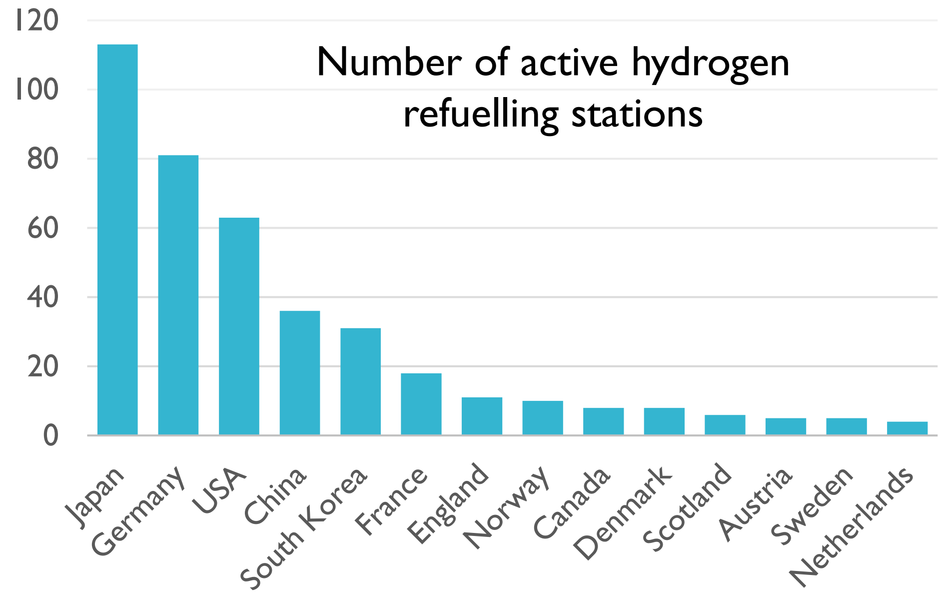
Export of green hydrogen is a large potential market.

Figure: Commonwealth of Australia, *Australia's National Hydrogen Strategy*

(Note figure modified from original)

Hydrogen utilisation

Transport (mobility) applications



- Various fuel cell powered vehicles (FCEVs) are available or under development; forklifts through to heavy haulage mining trucks. Note that these have an electric powertrain.
- Heavy vehicles (buses, trucks) are likely to be a focus for hydrogen technology due to higher vehicle weight and mileage.
- Rail, marine, and aviation under development.
- Currently two standard refuelling pressures 350 and 700 bar.
- Fuel economy depends on vehicle, duty cycle, environment;

  e.g. Passenger car: ~1 kg / 100 km. Bus: ~9 kg / 100 km
- Refuelling infrastructure is a significant issue. Need a well planned rollout strategy, and support for vehicle uptake.

Photo: Linde
Table: data sourced from https://h2tools.org/hyarc/hydrogen-delivery, and https://afdc.energy.gov/data_download)

Hydrogen utilisation

Heating applications

- Hydrogen is a potential option to replace fossil fuels for heating applications.
- Initially, hydrogen could be blended and injected into existing natural gas networks at a low percentage (e.g. 10% by volume). (Note that energy density by volume decreases with the addition of hydrogen.)
- Need to assess the compatibility of hydrogen with existing natural gas networks; pipeline, valves, compressors, metering, and end-use equipment/plant. (Tasmania's gas distribution network is relatively new and could potentially support a high hydrogen content.)
- Need to consider the potential impact of a variable blend on end use appliances/processes.
- Blending of hydrogen into the natural gas network is a different proposition to blending renewable electricity generation into the grid (different molecules versus same electrons).

Photo: ATCO

Hydrogen utilisation

Chemical / Industrial processes

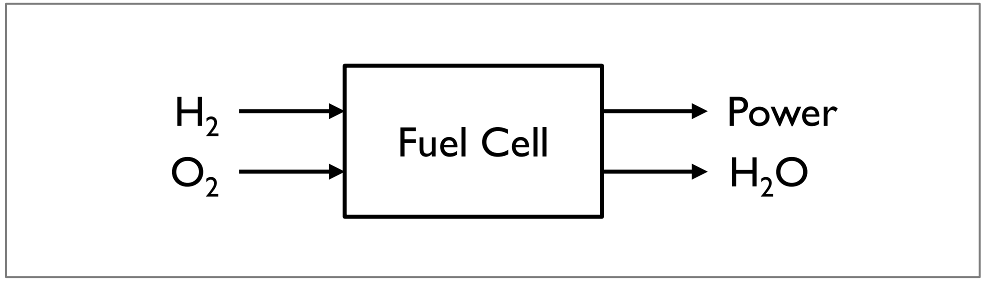
Industry/ product	Mt / year	Applications
Oil refining	38	Production of transport fuels, Hydrocracking and purification
Ammonia	31	Fertilisers, Explosives
Methanol	12	Plastics, Fuel additive
Steel	4	Direct reduction of iron ore

Source: IEA (2019). *The Future of Hydrogen*

- Hydrogen is used in many chemical and industrial processes.
- Existing applications range from oil refining, manufacture of ammonia (NH_3) and methanol (CH_3OH), through to glass manufacturing and food production.
- Key takeaway is that there is already large-scale usage of hydrogen around the world for different chemical and industrial applications.

Hydrogen utilisation

Electricity generation



Hydrogen can be used to generate electricity via two pathways:

1. Fuel cell (multiple types); electrochemical process.
2. Specialised hydrogen gas turbine or engine; combustion process. Need to consider NOx emissions from combustion.

Other considerations:

- Round-trip efficiency (electrolyser – hydrogen storage – fuel cell) is low compared to battery systems.
- Hydrogen storage duration and scale is an advantage over battery systems.
- Electrolysers and fuel cells could potentially provide grid services (e.g. FCAS), which could enable a secondary revenue stream.

Photo: Plug Power

Hydrogen for export

Characteristic	GH2[1]	LH2	TL-MCH	NH_3
Density [kg/m^3]	0.0852	70.8	769	682
Gravimetric H_2 content [wt%]	100	100	6.16	17.8
Volumetric H_2 content [kg/m^3]	0.0852	70.8	47.1	120.3

[1] Gas density at 1 atm, 15° C

Source: NIST, and Wijayanta A, et al. International Journal of Hydrogen Energy 2019; 44:15026-44.

There are multiple options for transporting bulk quantities of hydrogen:

- Liquid hydrogen (LH2)
- Ammonia (NH_3)
- Liquid organic hydrogen carriers (LOHC); multiple options including toluene-methylcyclohexane (TL-MCH) cycle

All approaches have a significant energy cost.

Selection of the best approach needs to consider the hydrogen end-use.

Challenges

Hydrogen production cost

CAPEX [$/kW]	750			
CAPEX [$/(kg/day)]	1,625			
LCOE [$/kWh]	0.025	0.050	0.060	0.070
Utilisation				
10%	6.20	7.50	8.02	8.54
20%	3.80	5.10	5.62	6.14
30%	3.00	4.30	4.82	5.34
40%	2.61	3.91	4.43	4.95
50%	2.37	3.67	4.19	4.71
60%	2.21	3.51	4.03	4.55
70%	2.09	3.39	3.91	4.43
80%	2.01	3.31	3.83	4.35
90%	1.94	3.24	3.76	4.28
100%	1.89	3.19	3.71	4.23

Note that values depend on parameter assumptions.

- COVID-19; supply chain, finance.
- Cost of equipment; electrolysers, compressors, fuel cells, vehicles, etc.
- Cost of hydrogen production compared to incumbent fossil fuel approaches. 'H2 under 2' target. (See table. Note CAPEX assumes low future value.)
- Chicken and egg issue for transport (mobility) applications.
- Transition from 100% natural gas to 100% hydrogen for heating; gas network and end-use compatibility considerations.
- Building local capability in hydrogen project design, installation, and O&M.
- Funding support is required on the supply and offtake sides.
- Competition from other jurisdictions.

Opportunities

Tasmania has a number of key competitive advantages:

- high renewable energy contribution, with hydropower firming
- access to abundant fresh water
- industrial precincts with available land and access to high quality infrastructure.

TRHAP update

- $50 million of support measures.
- Feasibility studies assessing green hydrogen, green ammonia, green methanol, and industrial heating have been recommended for support.
- A hydrogen demand study is currently underway, which will inform the next funding round. The aim is to get at least one operating project on the ground in Tasmania as early as possible.

Figure: DSG, *TRHAP*

Q&A

Photo: https://www.energiepark-mainz.de/en/project/pictures/

Contact details

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