Would hydrogen be capable of sustainably heating our homes?

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Speaker

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Product development: Low-entropy energy conversion, Ammonia production reactors, Turquoise hydrogen, Decarbonisation of marine transport

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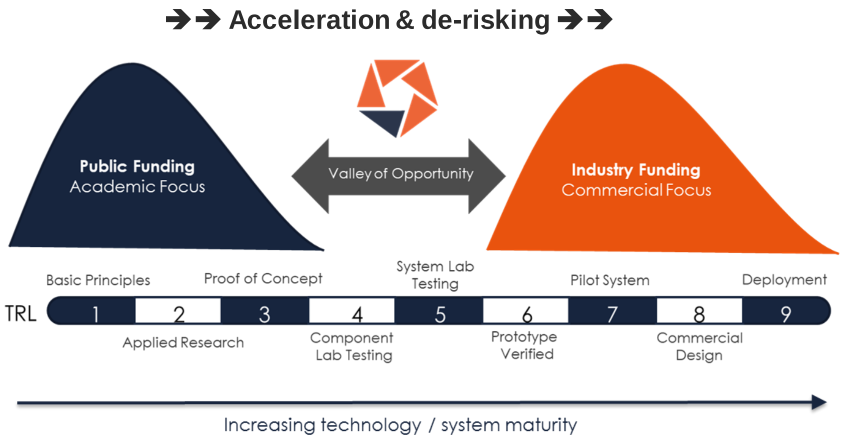
Scientific author, editor, & inventor

PNDC Overview

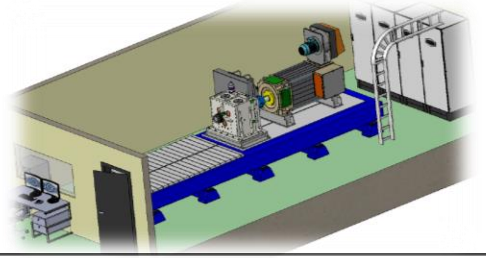
- University of Strathclyde industry-facing innovation centre opened in 2013 and currently celebrating a **decade of innovation** throughout 2023
- Focussed on accelerating the development and deployment of novel energy, marine and aerospace technologies supporting net zero initiatives
- Multiple engagement models:
    - Collaborative programmes in partnership with members
    - Open access for supporting all industry
- Dedicated expert team (~ 50 staff)
- New cutting-edge whole systems facility due in 2024



Whole Systems Facility

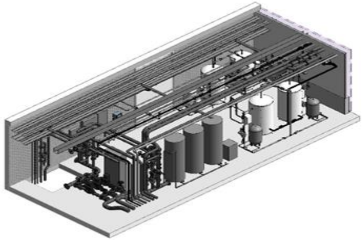
Electrical equipment (in procurement)

- 11kV distribution network
- 2.5MVA s/stn & LV network
- 1MVA DC power supply
- 1MVA AC power supply
- Real-time digital simulation
- 2 x 1MW dynamometers



Thermal facility (awaiting funding decision)

- For low carbon heating, cooling, thermal storage and heat recovery system testing and validation
- Scalable up to ~750kW, 5-90ºC flow temp, system ΔT 5-40ºC
- Heat and cooling emulators to mimic building heat demand



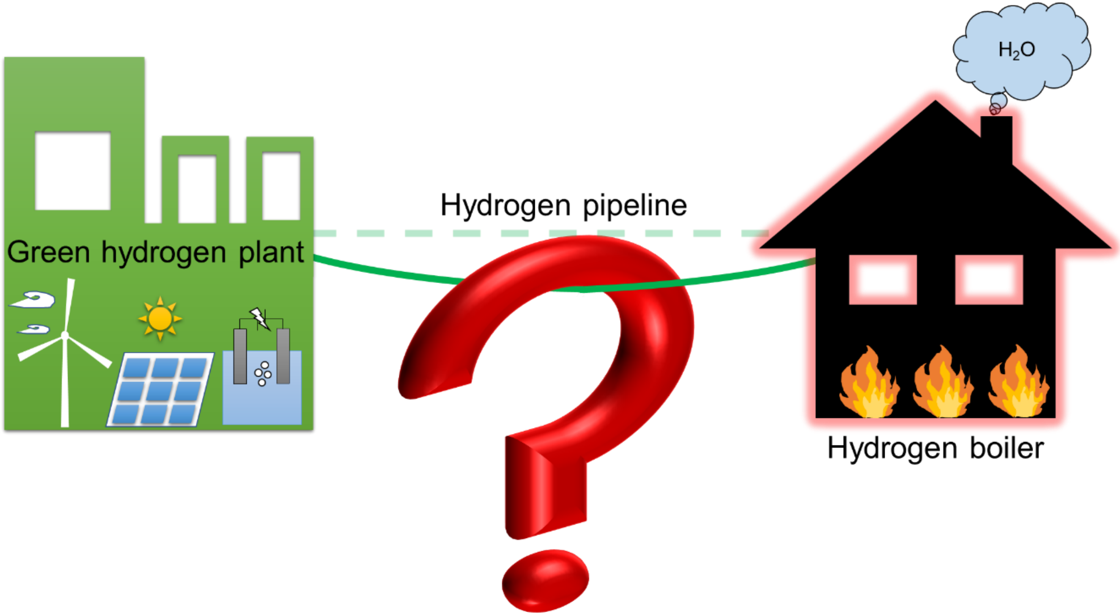
Hydrogen facility (existing + to be upgraded)

- Existing facility - 80 kg H_2 storage, 12 bar supply pressure, 9kg/hr max flowrate
- Upgraded facility - 160 kg H_2 storage, 20 bar supply pressure, 30kg/hr max flowrate

Whole system capability

Research Questions

- What are the challenges in resourcing green hydrogen?
- What are the challenges in the gas infrastructure?
- Can we expect emission-free heating if hydrogen or hydrogen blends flow in the pipelines?



Green Hydrogen Production

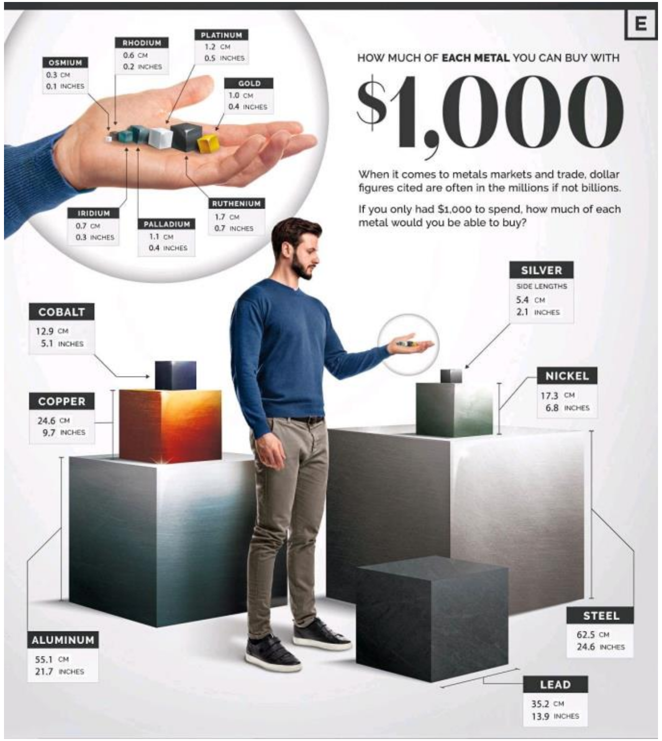
- Some of the raw materials required for various electrolysis technologies in the near future (by 2030).

Electrolyser technology →	PEM	AEM	Alkaline	SOEC and PCCE
Metallic elements required [kg/MW]	Pt: 0.3 Ir: 0.7 Ti: 500	Pt: 0.1 Ir: 0.3 Ti: 500	Ni: 800 C-steel: 10,000 Al: 500	Ni: 200 Zr: 40 La, Co: 20 Y: 5 S-steel: 10,000

Sources:
[M Chatenet et al. Chemical Society Reviews. 2022;51:4583-762]
[Bernuy-Lopez C. March 2023 #3. Hydate. https://hydate.substack.com/archive2023]
[N Chen et al. Energy & Environmental Science. 2021;14:6338-48]

Electrolyser technology →	PEM	AEM	Alkaline	SOEC and PCCE
pCapEx for Scotland's 2030 hydrogen economy target (5 GW)	£510 M	£250 M	£119 M	£50 M

Sources of individual metal prices:
[Institute of rare earths elements and strategic metals]
[TradingEconomics]



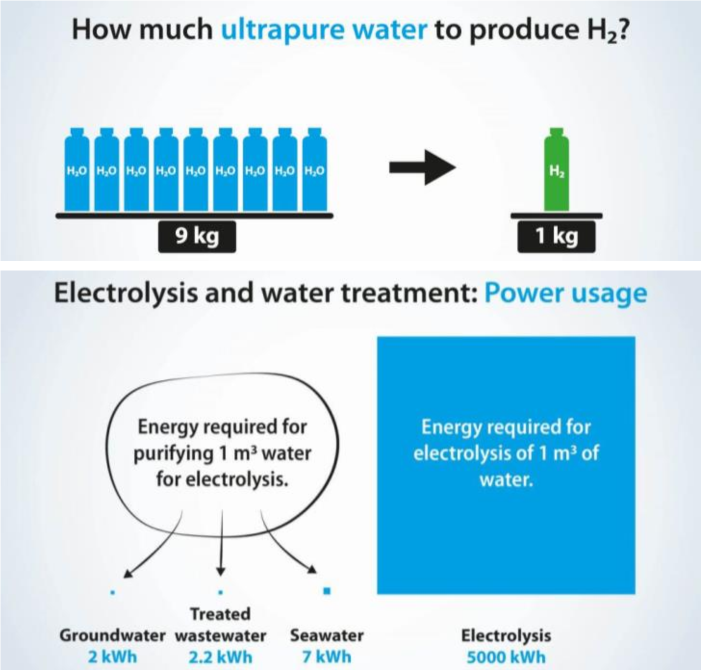
Sources:
[TradingEconomics]
[Elements.Visualcapitalist.com]

H2A Hydrogen Accelerator

Data under consideration for publication in *Applied Energy* and *Energy Findings*

Green Hydrogen Production (Scotland's 2030 Target)

- Scotland's target by 2030 → 15% of total energy demand = 5 GW of hydrogen



Source: *[Silhorko-Eurowater A/S]*

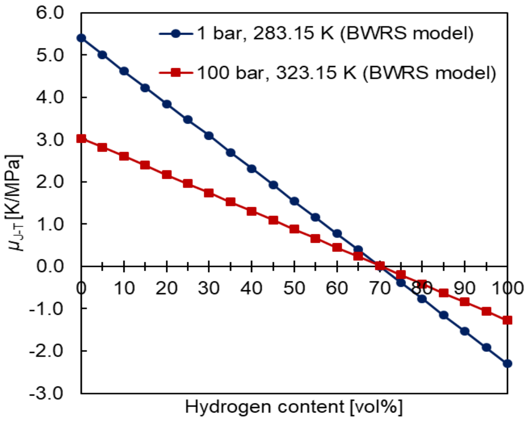
Electrolyser type	Required water for wet cooling [Mm³/yr]		Overall RE for cooling and electrolysis considering the capacity factor of 33.8% (Statista – Wind Offshore, 2021) [GW/yr]	
	Overall usage	Evaporated	Dry	Wet
PEM	32.6	24.5	24.8	20.3
AEM	37.2	27.9	28.2	23.1
Alkaline	32.6	24.5	24.8	20.3
SOEC	29.4	22.0	22.3	18.2

Transmission/Distribution

Hydrogen-enriched natural gas (HENG) scenario

1. HENG with H_2 content of up to 20–23 vol% is theoretically attainable using the existing boilers and infrastructure.
2. Up to 50 vol% of H_2 will require minor changes to the transmission/distribution and measuring equipment across the supply chain.
3. Above 50 vol%, however, major infrastructure change is required.
4. Safety and compatibility of the current infrastructure are highly compromised with H_2 content of over 70 vol%.

Joule-Thomson coefficient (μ_{JT})



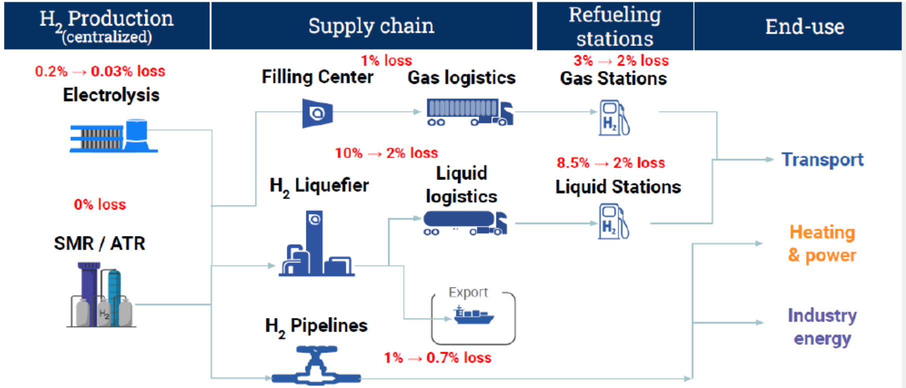
Source: *[J Li et al. ACS Omega. 2021;6:16722-35]*

Data under consideration for publication in *Applied Energy*

Transmission/Distribution

- 100% H_2 scenario

1. Environmental impact:



3 supply chains

⇒ Compressed gas:
today ~4.2% ⇒ 3% (2030)

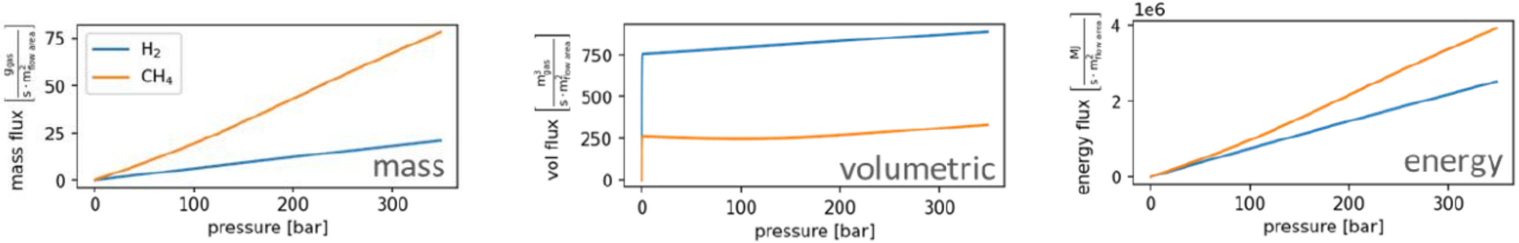
⇒ LH_2 :
today ~10-20% ⇒ 4-5% (2030)

⇒ pipelines:
today ~1.2% ⇒ <1% (2030)

Source: [Presentation by G. de Reals (Air Liquide)]

2. Economic impact:

- Takes 4 times the energy to transport H_2 instead of NG. *[IA Gondal et al. International Journal of Energy Research. 2012;36:1338-45]*

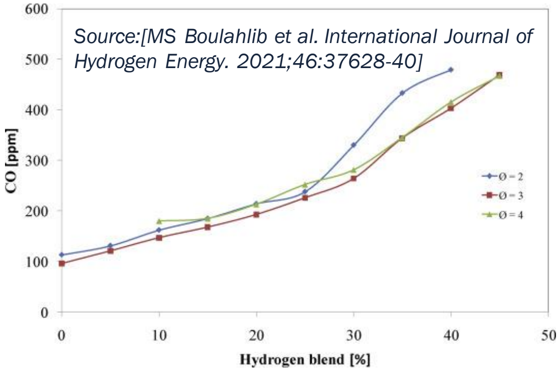


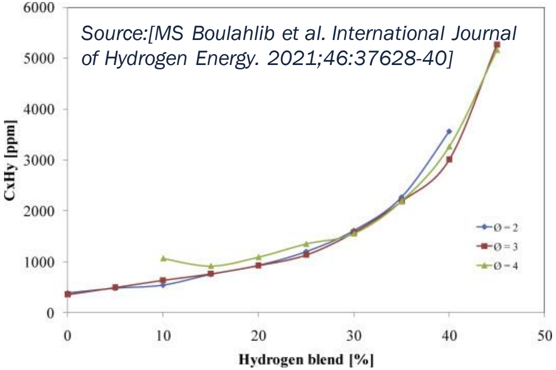
Source: [Sandia National Laboratories]

Data under consideration for publication in *Applied Energy*

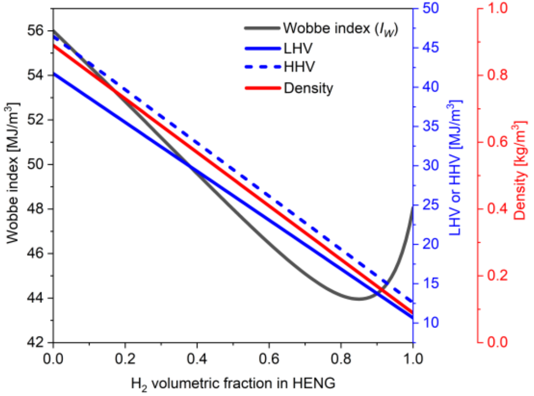
Combustion

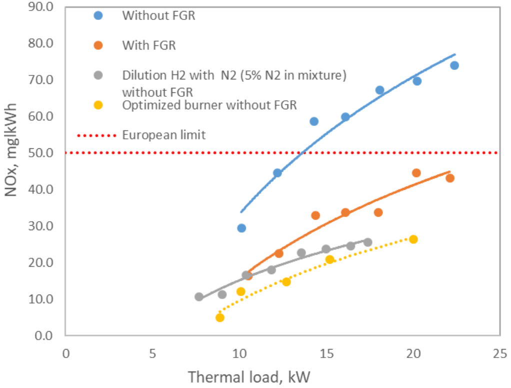
- Hydrogen-enriched natural gas (HENG) scenario





- 100% H_2 scenario





Source: [S Gersen et al. Conference: Domestic hydrogen boilers in practice: At: Oman. 2020]

Data under consideration for publication in *Applied Energy*

Key Findings and Recommendations

Findings:

- Solid oxide fuel cells and other high-efficiency electrolysis technologies make a great difference in CapEx for green hydrogen production.
- Appropriate water resourcing and plant sizing are essential to realising the heat decarbonisation goal.
- Hydrogen leakage from the gas pipelines is likely and may have adverse environmental effects rather than economic ones (assuming a competitive LCOH with natural gas).
- The integrity of transmission pipelines against H_2-induced degradation with pressure above 139 bar is uncertain.
- 100% hydrogen can eliminate the emissions, but carbon monoxide, new hydrocarbon species, and unburnt hydrocarbons may be emitted by hydrogen-enriched natural gas.

Recommendations:

- The boiler manufacturers are highly encouraged to publish their test results regarding the emissions of their H_2-ready and/or H_2-only boilers.
- Green hydrogen requires major investments. Other low-to-zero-carbon hydrogen (pink, turquoise, blue, natural hydrogen in geysers) technologies will be necessary to meet the overall hydrogen demand.
- Heat pumps and new disruptive heating technologies, active or passive, must be pursued in parallel.

UNIVERSITY of STRATHCLYDE PNDC A DECADE OF INNOVATION

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Final Statement

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