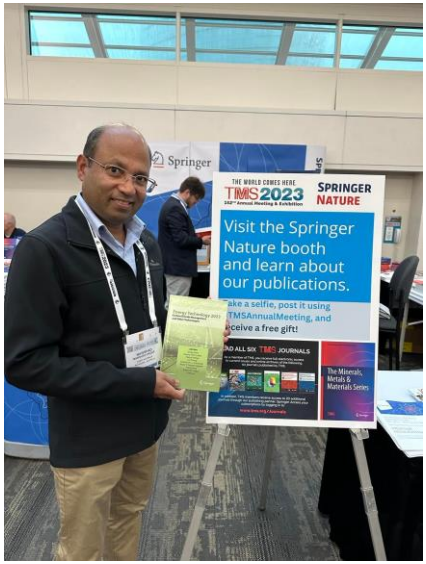
Hydrogen As An Alternative Energy Carrier

Dr Nawshad Haque | 11 June 2023
Team Leader (Techno-economic and Decarbonisation)

Meeting with Bangladesh Energy Society

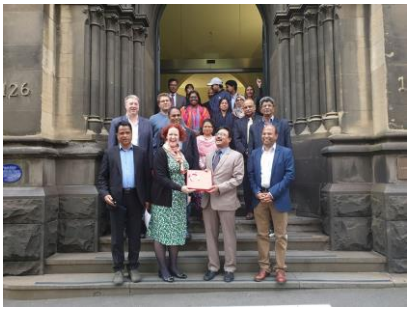
About the Presenter

- Originally from Bangladesh with Bachelor of Science
- Master of Science from the University of Wales, Bangor UK
- Principal Scientist at CSIRO and leads Research Team and multiple large projects on Energy, Mining and Mineral Processing, Metal Production Technologies
- PhD in Chemical Engineering from University of Sydney in 2002
- Fellow of the Australasian Institute of Mining and Metallurgy, and Australian Institute of Energy
- Researching on technology evaluation, techno-economic and life cycle assessment of energy systems (hydrogen) and a variety of metals, including steel, aluminium, copper, magnesium, ferroalloy, gold, nickel and rare earth and critical metals to identify opportunities for CO_2 emission reduction.




4
QUALITY
EDUCATION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

With Science Minister of Bangladesh, Yeafesh Osman.



With Bangladesh Delegation at RMIT

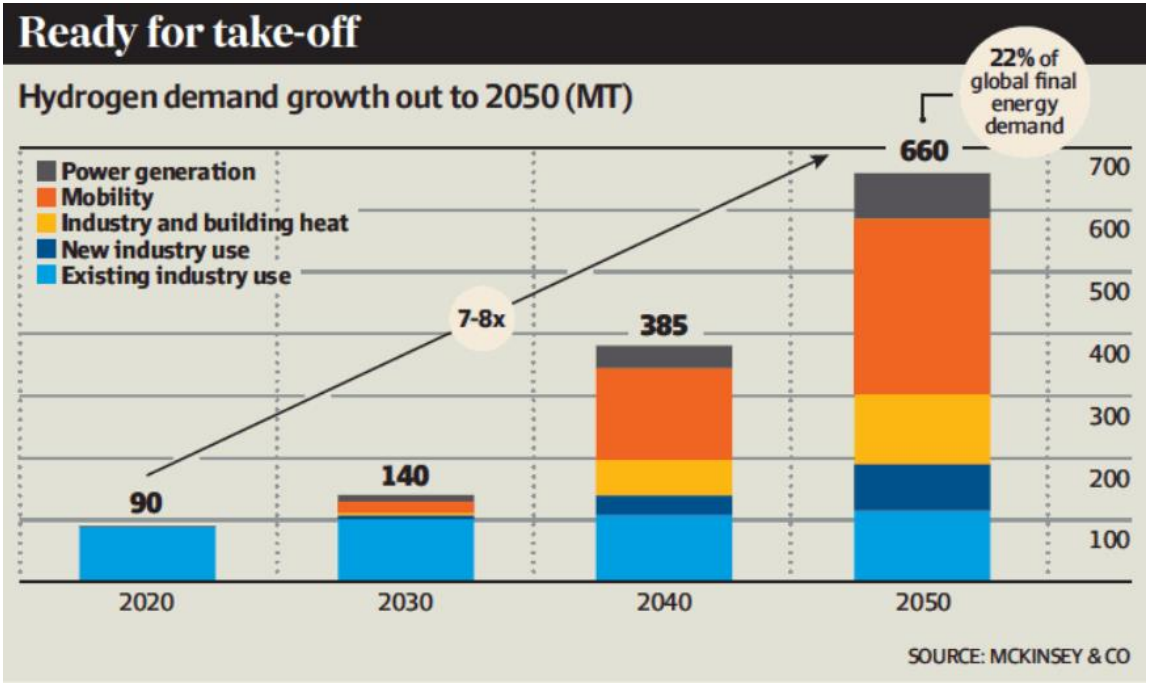
With Victorian Premier Daniel Andrews and MP Julian Hill.

Afghan Ministry Officials and Australian Consul in Kolkata, India.

Q & A

1. Present Status of Hydrogen Fuel;
2. Technology (i.e. turbine, generator) available at this moment;
3. Price of HF in global market;
4. Which countries are leading HF in the global market?
5. How much HF is required to generate One MW power?
6. Prospects of introducing HF in Bangladesh;
7. Challenges;
8. Recommendations etc.

Why Hydrogen?



1. Present Status of Hydrogen Fuel

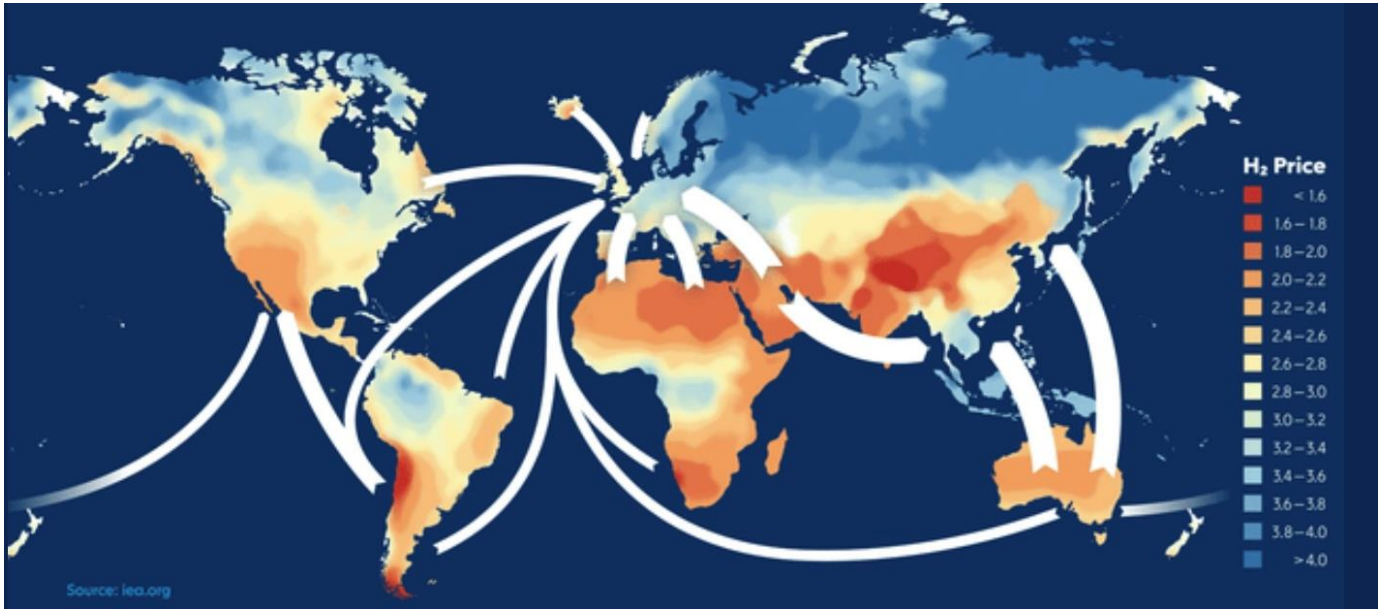
	Terminology	Technology	Feedstock/ Electricity source	GHG footprint*
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal	Minimal
	Purple/Pink Hydrogen		Nuclear	
	Yellow Hydrogen		Mixed-origin grid energy	Medium
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal	Low
	Turquoise Hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey Hydrogen	Natural gas reforming		Medium
	Brown Hydrogen	Gasification	Brown coal (lignite)	High
	Black Hydrogen		Black coal	

*GHG footprint given as a general guide but it is accepted that each category can be higher in some cases.

Source: Cheng and Lee, 2022, Sustainability https://www.mdpi.com/2071-1050/14/3/1930

2. Technology Status

3. H_2 Price (Forecast in Future)



5. How much H_2 fuel is required for 1 MW?

- ≈55 kWh electricity input for producing 1 kg H_2 fuel (water electrolysis technology) ≈ 11.1 m^3 at STP
- 1 kg H_2 has ≈ 120 MJ (LHV) ≈ 33.3 kWh energy
- Fuel cell efficiency ≈ 55%
- Net electrical power output ≈ 18.3 kWh
- H_2 fuel required for 1 MWh electricity output ≈ 54.6 kg H_2 or \$110/MWh @\$2/kg H_2 *with no CO_2*

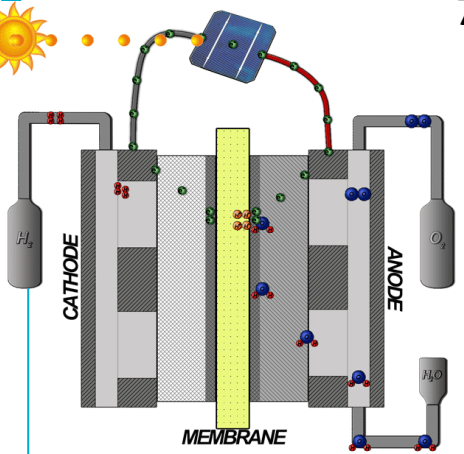
- Total km travelling possible ≈ 110 km by car
- Market price in the US ≈ \$16/kg H_2
- @\$1.5/L petrol, 15 L petrol is required for 110 km, or ≈ \$23.6 or 48% more for fuel cost but petrol car is ≈30-40% cheaper with high CO_2

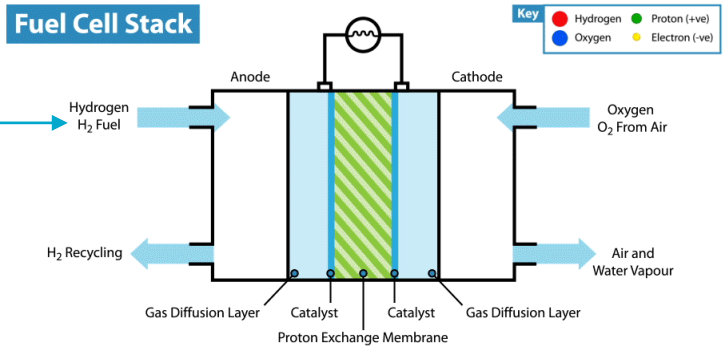
6. Prospect of H_2 Fuel in Bangladesh

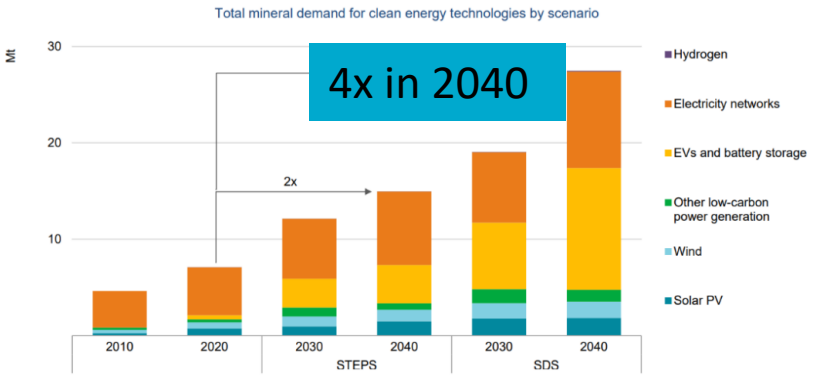
- Wind potential (particularly *offshore*) ≈ 20 GW gross capacity (Japanese estimate) ≈ @0.4 factor 8 GW net capacity
- ≈1.2 Mtpa H_2 ≈39,000 GWh energy equivalent or 21,000 GWh electricity output from a fuel cell technology, or at steady operation ≈ 2.7 GW net electric power output
- ***Investment to be estimated***, potentially ≈$2.4 B p.a. revenue @$2/kg H_2
- Oxygen more than ≈ 5 times as by-product (medical, industry uses, net enclosed sea fish farming), @$200/t O_2, $1.2 B p.a.

- Output electric power is a cheap low value product from H_2
- If dumping of electric load from nuclear or grid is required - making H_2 is good as a product or sink
- Think to use as chemical for *ammonia* and then ***urea***
- Better to plan for future use as transport fuel for cars, buses, trucks when cheaper automotive vehicle technologies are available

7. Challenges







*International Energy Agency, The Role of Critical Minerals in Clean Energy Transitions (2021) **

Australia Bangladesh Collaboration

Dr Nawshad Haque | CSIRO Australia

https://rd20.aist.go.jp/rd20_cms/wp-content/uploads/2022/11/1_1_Nawshad-Haque.pdf

Techno-Economic Analysis of Renewable Hydrogen and Ammonia Supply Chains

4th RD20 Conference 2022

Nawshad Haque | 4 October 2022

CSIRO's PEM electrolyser technology

- Developed technology to kW scale Hydrogen production for distributed applications.
- Spun off a company "Endua" for commercialisation of technology for off-grid power and diesel replacement market.

ENDUA

MAIN SEQUENCE
CSIRO Innovation Fund

AMPOL

The Endua power bank - a long duration energy storage product

Power Banks
- Self-contained, easily deployable & relocatable
- On-site H2 generation & storage

Infinite Energy Storage - Resilience & Self-sufficiency
- Scalable modular system
- Additional energy storage at marginal cost

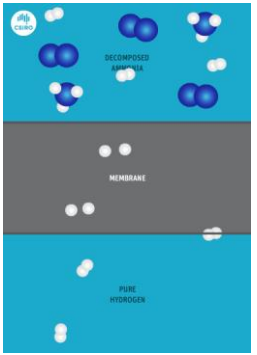
Affordable Reliable Power
- Designed, sized & priced to supplant diesel generators
- On-demand power days/weeks/months after generation

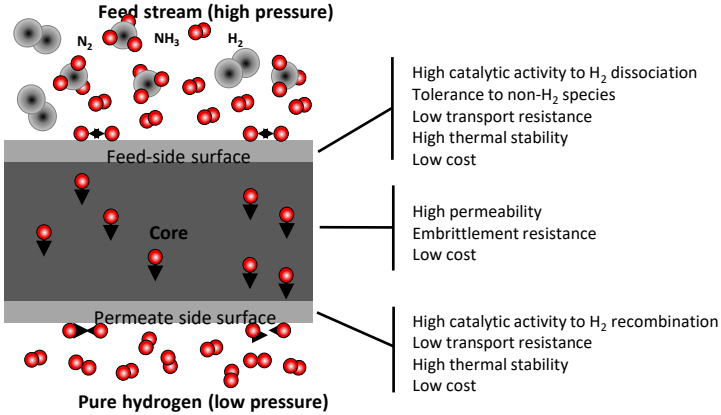
Meet Sustainability Goals
- Zero emission tech, 100% renewable power when needed

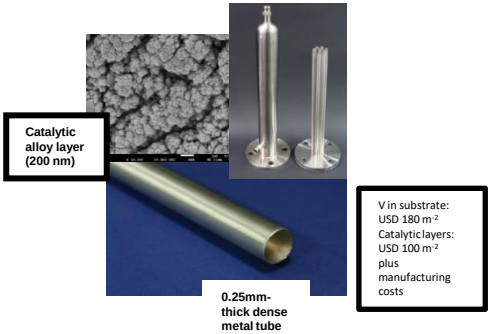
ENDUA

CSIRO's metal membrane H_2 separation technology

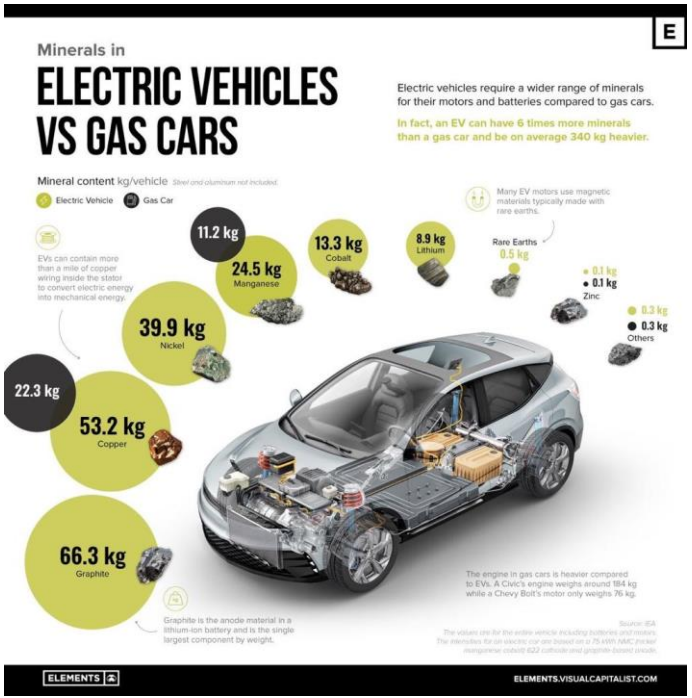
- Separation of H_2 from ammonia-derived mixed gas streams
- This concept can also be applied to NG reforming, CO shift, or any process with H_2 as a product.

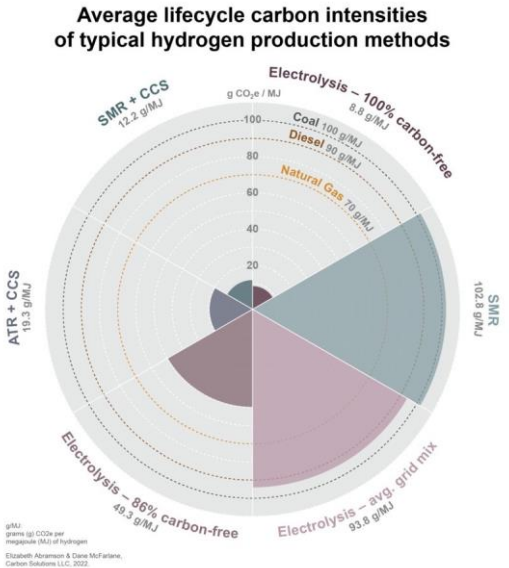






Fuel cell EV refuelling with H_2 from ammonia



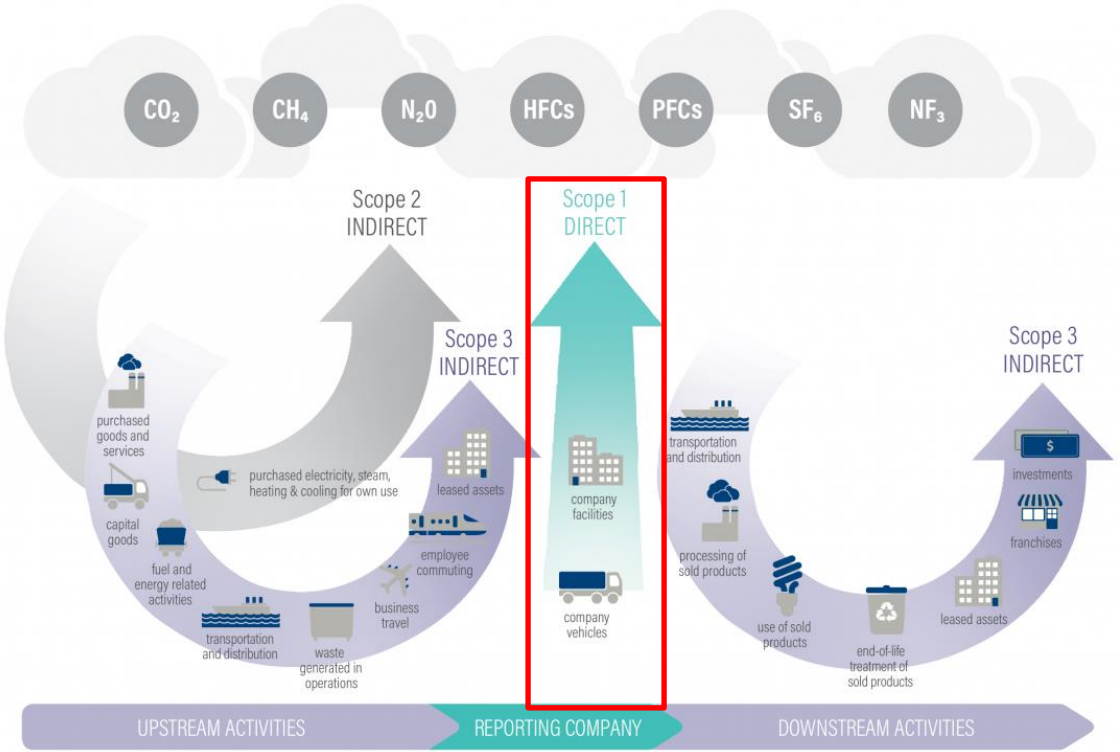


From coal - 12 kg CO_2-e/kg H_2

vs

Renewable - 1 kg CO_2-e/kg H_2

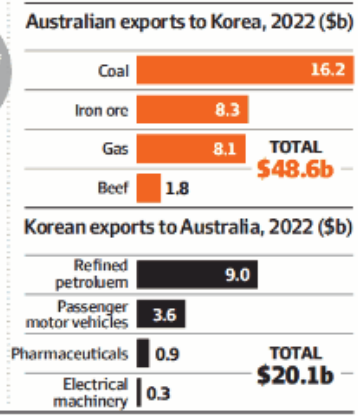
CO_2 equivalent emission

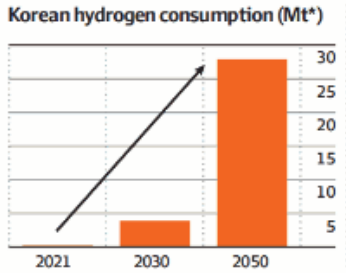


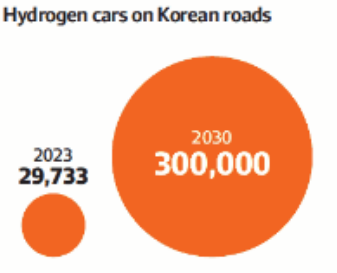
H_2 & EV Opportunities

Window of opportunity

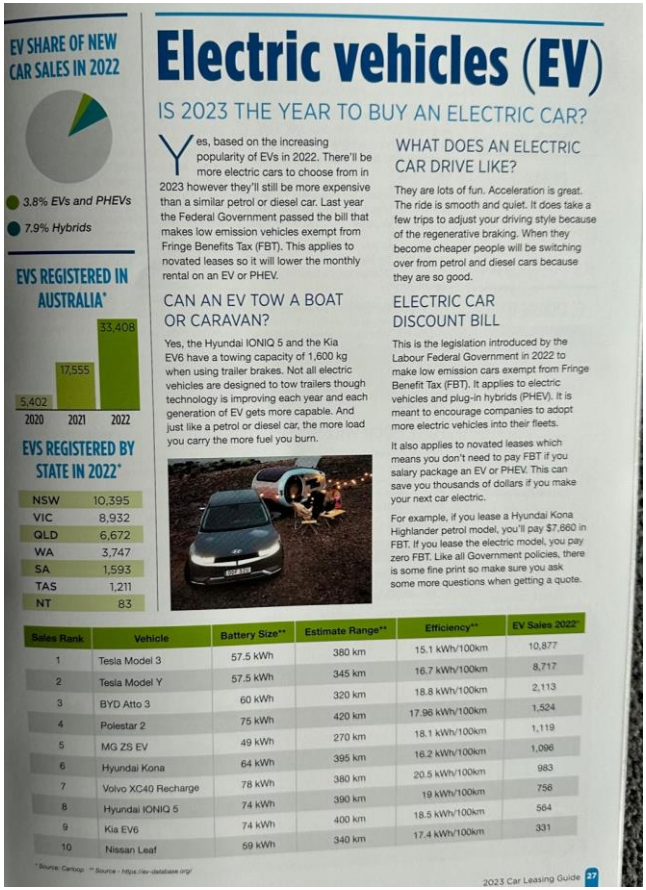
How hydrogen could be the future of Australia's trade relationship with Korea



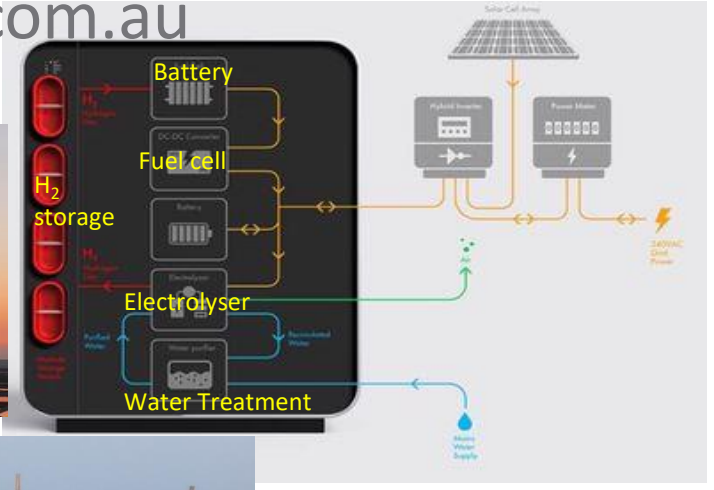




SOURCE: DFAT, ABS, KOREAN GOVERNMENT



Lavo System - lavo.com.au



TECHNICAL SPECS

Mechanical

Dimensions (HxWxD)	1680 x 1240 x 400 mm
Weight	196 kg
Hydride Vessels	4 vessels
Max System Pressure	35 bar_g
Vessel Weight	32 kg
Total Installed Weight	324 kg
Mounting	Floor Mount / Outdoors

Environmental

Operational Temperature Range	-10° to +50° C
Recommended Temperature Range	5° to 45° C
Environmental Humidity Range	3 to 100% RH
Maximum Elevation	2000 m
Noise Level	< 45 dB
Enclosure Protection Rating	IP54

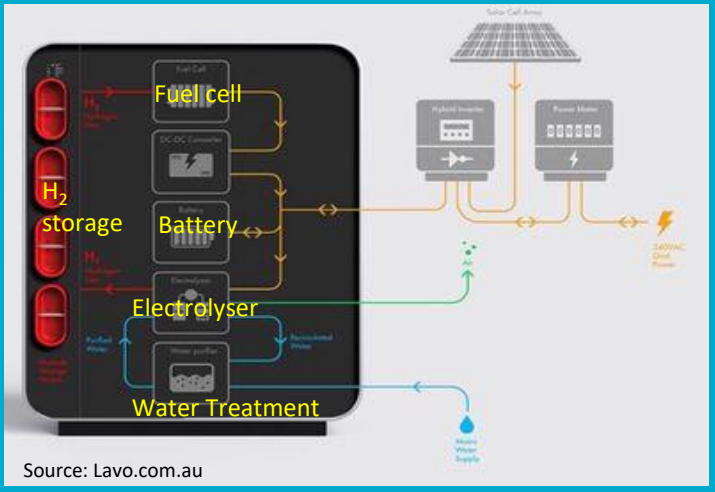
Performance

Usable Capacity	40 kWh
Real Power, max continuous	5 kW (charge and discharge)
Nominal Voltage	48 V DC
Output Voltage Range	45 – 53 V DC
Hydride Cycles	< 20,000
Warranty	10 years
Lifetime	30 years

Connections

Water Supply	Portable Mains Water / LAVO™ water purification unit
Communication	Local WiFi / Ethernet / 4G / 5G

Sources: Various websites



Source: Lavo.com.au

Thank you

Energy
Dr Nawshad Haque
Principal Scientist

Team Leader (Technoeconomic for Decarbonisation)

+61 3 9545 8931 M 0434141506
Nawshad.Haque@csiro.au
Web: https://people.csiro.au/H/N/Nawshad-Haque
LinkedIn: https://www.linkedin.com/in/nawshad-