



Hydrogen As An Alternative Energy Carrier

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

Meeting with Bangladesh Energy Society

Broken Hill - 53 MW, 140 ha
A\$257M 2017





About the Presenter

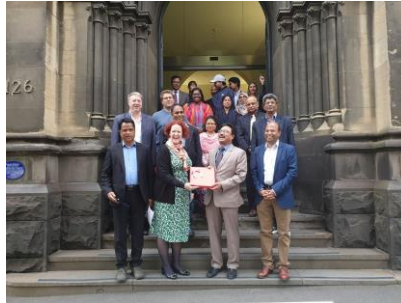
- Originally from Bangladesh with Bachelor of Science
- Master of Science from the University of Wales, Bangor UK
- Principal Scientist at CSIRO and leads Research Team and multiple large projects on Energy, Mining and Mineral Processing, Metal Production Technologies
- PhD in Chemical Engineering from 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 CO₂ emission reduction.







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.

Dr Nawshad Haque | CSIRO Australia

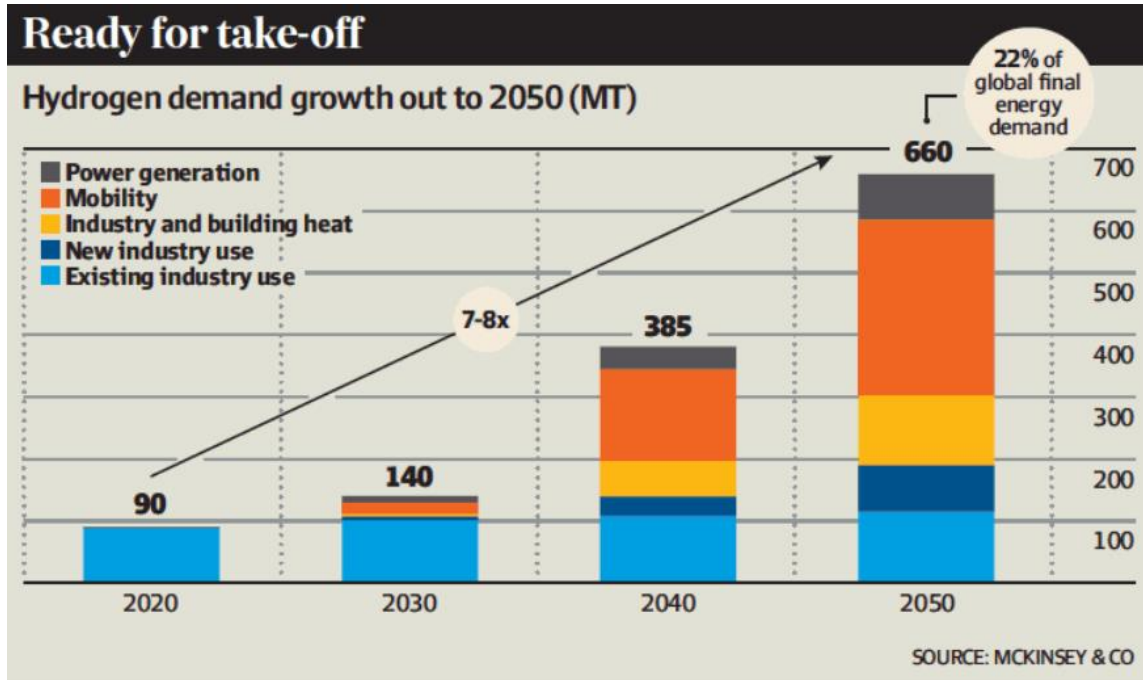




Q & A

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	

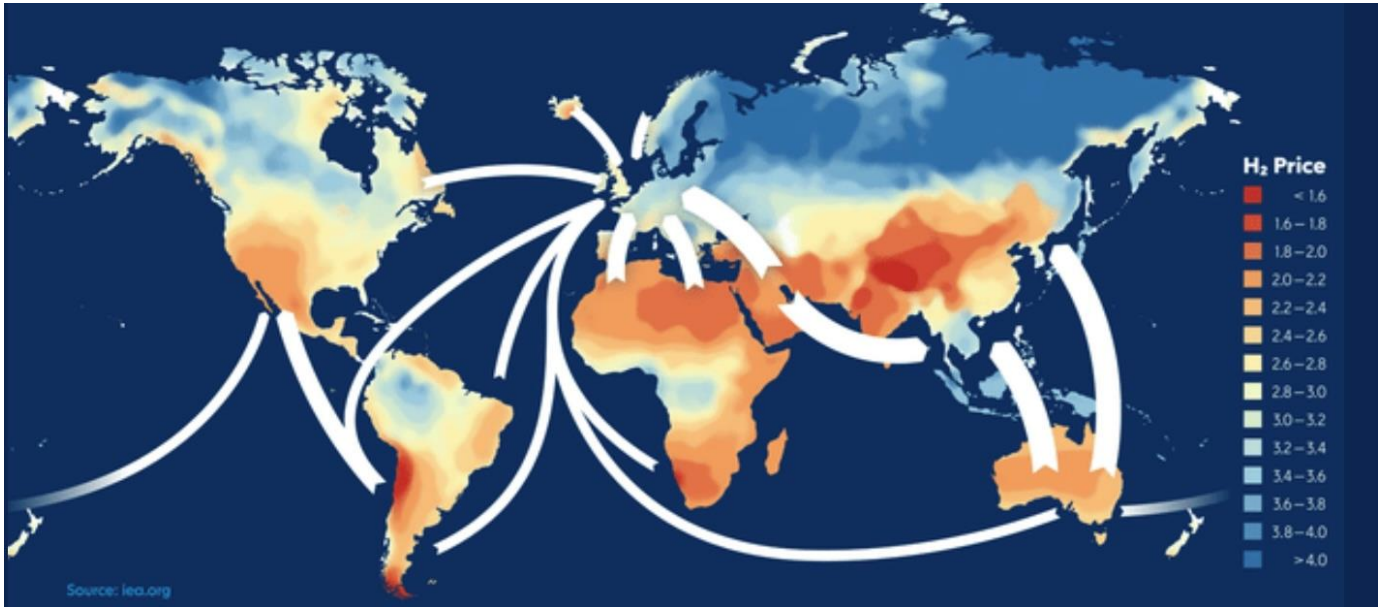
*GHG footprint given as a general guide but it is accepted that each category can be higher in some cases.

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

2. Technology Status



3. H₂ Price (Forecast in Future)





5. How much H₂ fuel is required for 1 MW?

- ≈ 55 kWh electricity input for producing 1 kg H₂ fuel (water electrolysis technology) ≈ 11.1 m³ at STP
- 1 kg H₂ has ≈ 120 MJ (LHV) ≈ 33.3 kWh energy
- Fuel cell efficiency $\approx 55\%$
- Net electrical power output ≈ 18.3 kWh
- H₂ fuel required for 1 MWh electricity output ≈ 54.6 kg H₂ or \$110/MWh @ \$2/kg H₂ with no CO₂
- Total km travelling possible ≈ 110 km by car
- Market price in the US \approx \$16/kg H₂
- @\$1.5/L petrol, 15 L petrol is required for 110 km, or \approx \$23.6 or 48% more for fuel cost but petrol car is ≈ 30 -40% cheaper with high CO₂

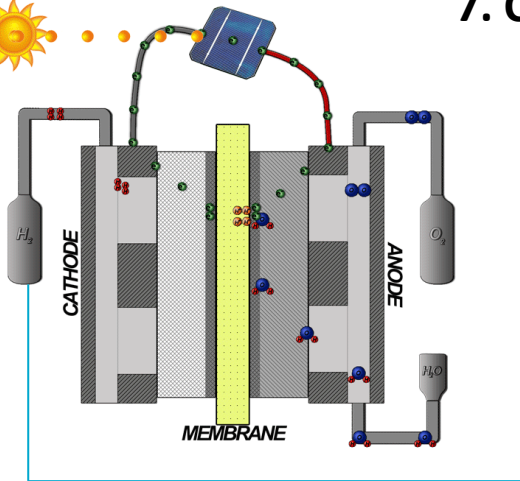


6. Prospect of H₂ Fuel in Bangladesh

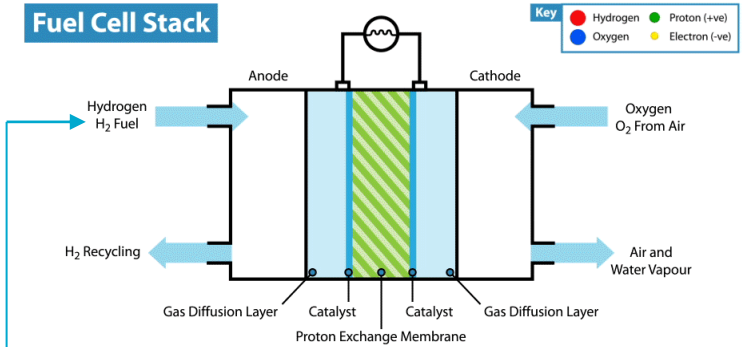
- Wind potential (particularly *offshore*) \approx 20 GW gross capacity (Japanese estimate) \approx @0.4 factor 8 GW net capacity
- \approx 1.2 Mtpa H₂ \approx 39,000 GWh energy equivalent or 21,000 GWh electricity output from a fuel cell technology, or at steady operation \approx 2.7 GW net electric power output
- **Investment to be estimated**, potentially \approx \$2.4 B p.a. revenue @\$2/kg H₂
- Oxygen more than \approx 5 times as by-product (medical, industry uses, net enclosed sea fish farming), @\$200/t O₂, \$1.2 B p.a.
- Output electric power is a cheap low value product from H₂
- If dumping of electric load from nuclear or grid is required - making H₂ 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



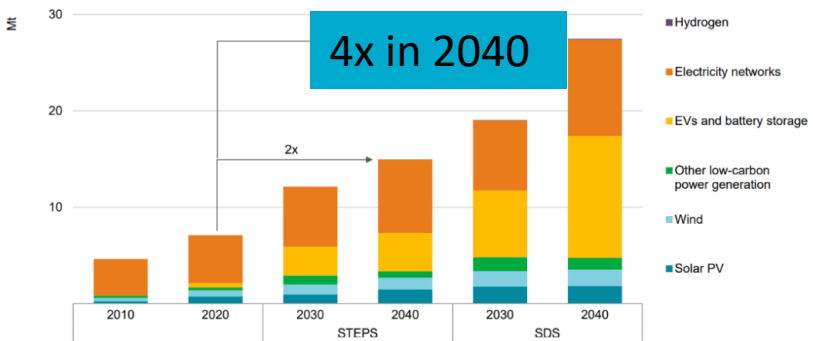
7. Challenges



Fuel Cell Stack



Total mineral demand for clean energy technologies by scenario



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



Australia Bangladesh Collaboration





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



The Endua power bank - a long duration energy storage product



Power Banks

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



Affordable Reliable Power

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



Infinite Energy Storage - Resilience & Self-sufficiency

- Scalable modular system
- Additional energy storage at marginal cost



Meet Sustainability Goals

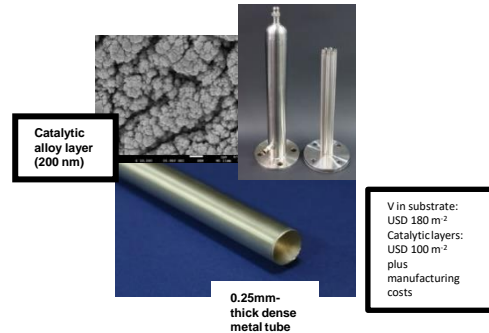
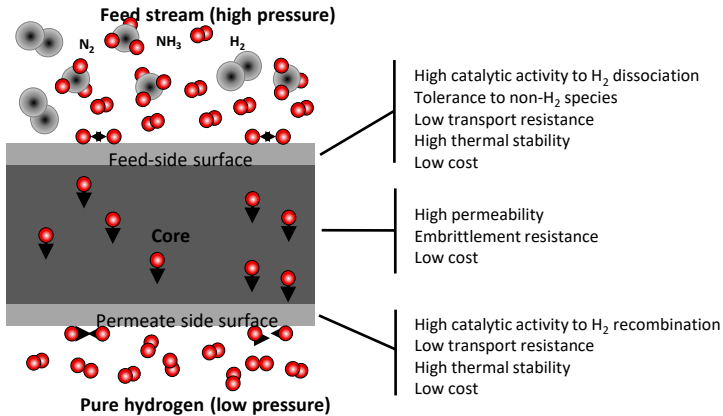
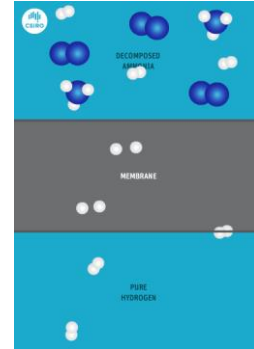
- Zero emission tech, 100% renewable power when needed

ENDUA

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CSIRO's metal membrane H₂ separation technology

- Separation of H₂ from ammonia-derived mixed gas streams
- This concept can also be applied to NG reforming, CO shift, or any process with H₂ as a product.



Fuel cell EV refuelling with H₂ from ammonia

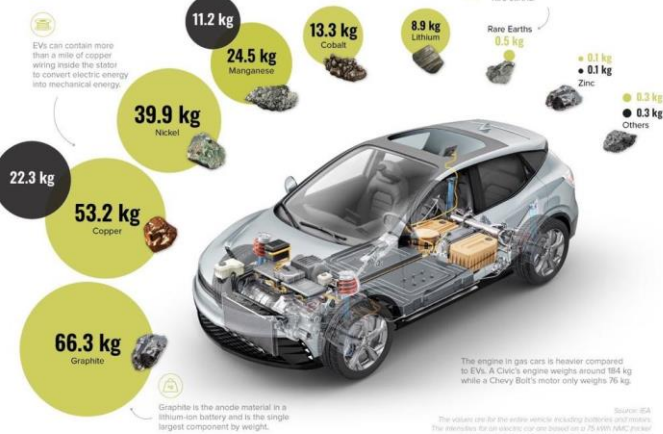


Minerals in ELECTRIC VEHICLES VS GAS CARS

Mineral content kg/vehicle *Steel and aluminum not included*

● Electric Vehicle ● Gas Car

EVs can contain more than a mile of copper wiring inside the stator to convert electric energy into mechanical energy.



Electric vehicles require a wider range of minerals for their motors and batteries compared to gas cars.

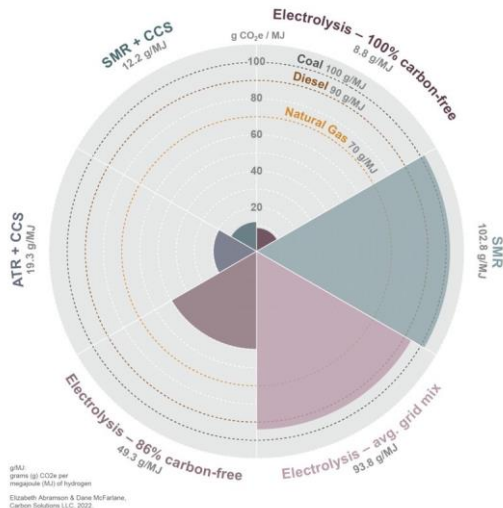
In fact, an EV can have 6 times more minerals than a gas car and be on average 340 kg heavier.

Many EV motors use magnetic materials typically made with rare earths.

The engine in gas cars is heavier compared to EVs. A Civic's engine weighs around 184 kg while a Chevy Bolt's motor only weighs 76 kg.

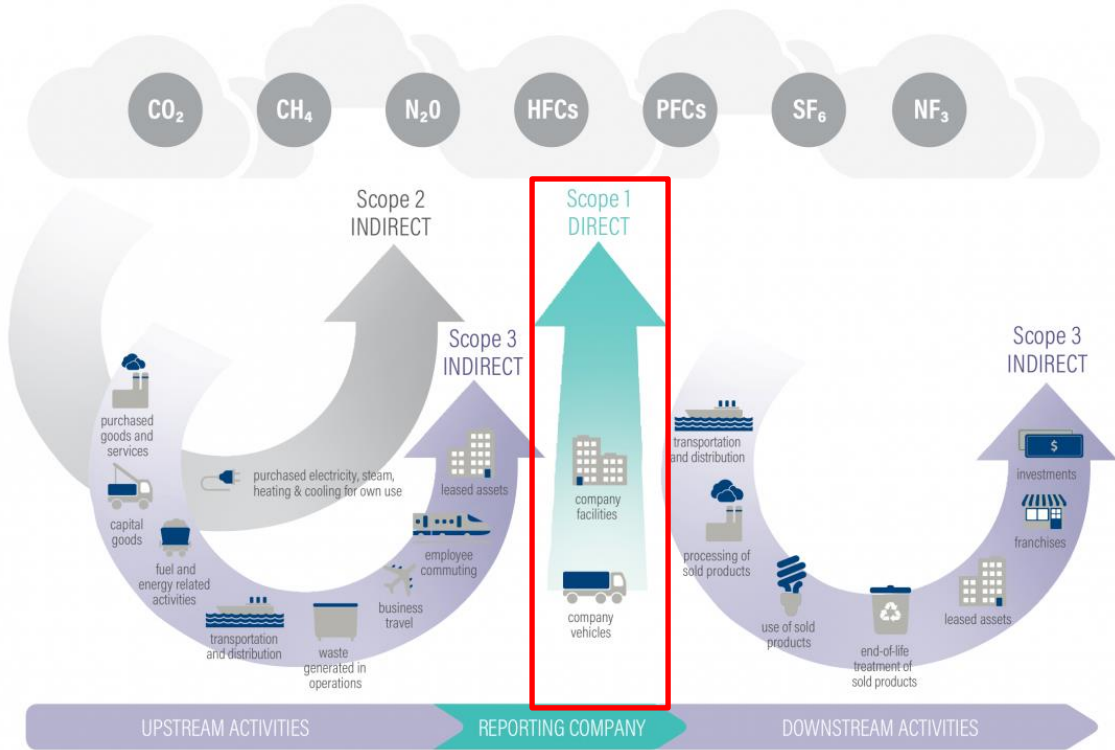
Source: IEA
The values are for the entire vehicle including battery and engine. The minerals for an electric car are based on a 75 kWh NMC, the current widespread EV battery type. Approximate values.

Average lifecycle carbon intensities of typical hydrogen production methods



From coal - 12 kg
CO₂-e/kg H₂
VS
Renewable - 1 kg
CO₂-e/kg H₂

CO₂ equivalent emission



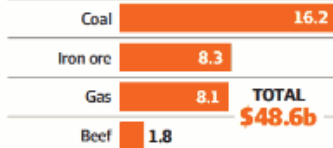
H₂ & EV Opportunities

Window of opportunity

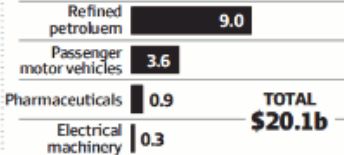
How hydrogen could be the future of Australia's trade relationship with Korea



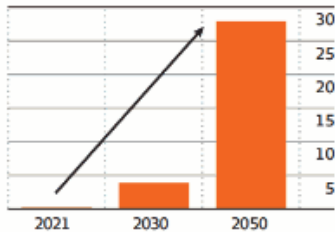
Australian exports to Korea, 2022 (\$b)



Korean exports to Australia, 2022 (\$b)

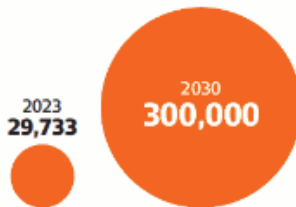


Korean hydrogen consumption (Mt*)



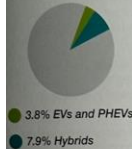
*Million tonnes

Hydrogen cars on Korean roads

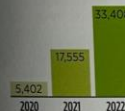


SOURCE: DFAT, ABS, KOREAN GOVERNMENT

EV SHARE OF NEW CAR SALES IN 2022



EVs REGISTERED IN AUSTRALIA*



EVs REGISTERED BY STATE IN 2022*

NSW	10,395
VIC	8,932
QLD	6,672
WA	3,747
SA	1,593
TAS	1,211
NT	83

Electric vehicles (EV)

IS 2023 THE YEAR TO BUY AN ELECTRIC CAR?

Yes, based on the increasing popularity of EVs in 2022. There'll be more electric cars to choose from in 2023 however they'll still be more expensive than a similar petrol or diesel car. Last year the Federal Government passed the bill that makes low emission vehicles exempt from Fringe Benefits Tax (FBT). This applies to novated leases so it will lower the monthly rental on an EV or PHEV.

WHAT DOES AN ELECTRIC CAR DRIVE LIKE?

They are lots of fun. Acceleration is great. The ride is smooth and quiet. It does take a few trips to adjust your driving style because of the regenerative braking. When they become cheaper people will be switching over from petrol and diesel cars because they are so good.

CAN AN EV TOW A BOAT OR CARAVAN?

Yes, the Hyundai IONIQ 5 and the Kia EV6 have a towing capacity of 1,600 kg when using trailer brakes. Not all electric vehicles are designed to tow trailers though technology is improving each year and each generation of EV gets more capable. And just like a petrol or diesel car, the more load you carry the more fuel you burn.

ELECTRIC CAR DISCOUNT BILL

This is the Federal Government introduced by the Labour Federal Government in 2022 to make low emission cars exempt from Fringe Benefits Tax (FBT). It applies to electric vehicles and plug-in hybrids (PHEV). It is meant to encourage companies to adopt more electric vehicles into their fleets.

It also applies to novated leases which means you don't need to pay FBT if your salary package an EV or PHEV. This can save you thousands of dollars if you make your next car electric.

For example, if you lease a Hyundai Kona Highlander petrol model, you'll pay \$7,680 in FBT. If you lease the electric model, you pay zero FBT. Like all Government policies, there is some fine print so make sure you get a quote.

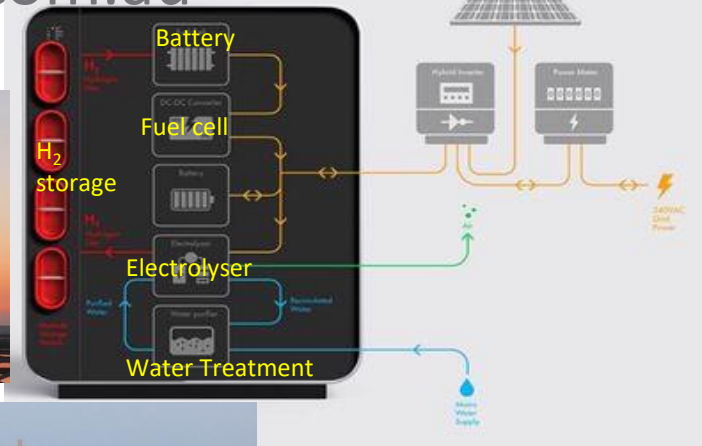


Sales Rank	Vehicle	Battery Size**	Estimate Range**	Efficiency**	EV Sales 2022
1	Tesla Model 3	57.5 kWh	380 km	15.1 kWh/100km	10,877
2	Tesla Model Y	57.5 kWh	345 km	16.7 kWh/100km	8,717
3	BYD Atto 3	60 kWh	320 km	18.8 kWh/100km	2,113
4	Polestar 2	75 kWh	420 km	17.96 kWh/100km	1,524
5	MG ZS EV	49 kWh	270 km	18.1 kWh/100km	1,119
6	Hyundai Kona	64 kWh	395 km	16.2 kWh/100km	1,096
7	Volvo XC40 Recharge	78 kWh	380 km	20.5 kWh/100km	983
8	Hyundai IONIQ 5	74 kWh	390 km	19 kWh/100km	756
9	Kia EV6	74 kWh	400 km	18.5 kWh/100km	564
10	Nissan Leaf	59 kWh	340 km	17.4 kWh/100km	331

*Source: Carloop **Source: <https://ev-database.org/>

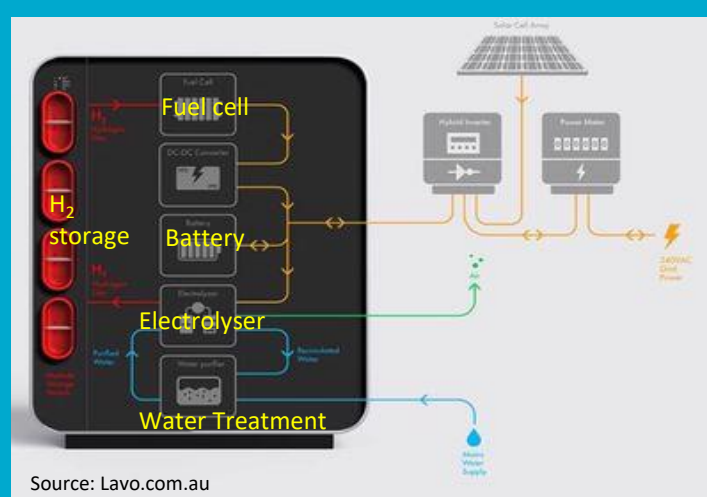


Lavo System - lavo.com.au



TECHNICAL SPECS

Mechanical	Performance
Dimensions (HxWxD)	1680 x 1280 x 400 mm
Weight	196 kg
Hydride Vessels	4 vessels
Max System Pressure	35 Bar
Vessel Weight	32 kg
Total Installed Weight	328 kg
Mounting	Floor Mount / Outdoors
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	< 65 dB
Enclosure Protection Rating	IP54
Stable 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



Thank you

Energy

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