LAVO Hydrogen Storage Technology

Clean Energy Systems

Jan 2025

LAVO Hydrogen

Who is LAVO?

LAVO is an Australian clean-tech company pioneering the future of clean energy driven by our unwavering commitment to making clean energy more **accessible, affordable, and dependable**

Our Vision

Change the way people live with Energy.

Our Story

Since 2020, LAVO has established its footprints in two **business units** - Hydrogen Energy Storage Solution and Lithium Battery solution across residential and commercial sectors.

In 2024, LAVO embarked on a strategic repositioning initiative, delineating two distinct units into **standalone business entities**. Under this transformative strategy, ***LAVO's HQ in Australia and its Japan office emerged as the primary drivers of the hydrogen sector, heralding a new era of leadership and innovation in the industry.***

Our Values

LAVO is a purpose driven and values led innovation company.

Our values under pin everything we do:

1. Positive Impact
2. Unconventional Solutions
3. Do the right thing
4. Empowered Collaboration
5. Authentic Inclusivity

Over a decade of research empowers LAVO Hydrogen to seize key opportunities in the industry

UNSW AUSTRALIA

LAVO

Theoretical research on metal hydrides

Transforming research outcomes into business opportunities

Building teams & brands & executing strategies

Introducing industry partners & establishing ecosystems

Conducting research and development for product commercialisation

Expand Product lines & manufacturing capability

Providence Climate Capital seeking a long-term energy storage solution

Providence Climate Capital

PCC confirms LDES opportunities in the market

2009

Lab established; initiating research on hydrides – Global leading hydrogen storage technology

PCC has established HERC with UNSW to facilitate commercialisation of technology.

Patent applications

2020

LAVO established

IP registration

Release of LAVO Resi-HESS and received global orders

2021

8 HESS prototype pilot sites deployed

Secured Gov grants for R&D

2022

Australian Government

2023

Marubeni 丸紅株式会社

Extend Product Line to LAVO Telco-HESS

Export of Green Hydrogen from Australia to Indonesia. Obtain World First IMDG Certificate

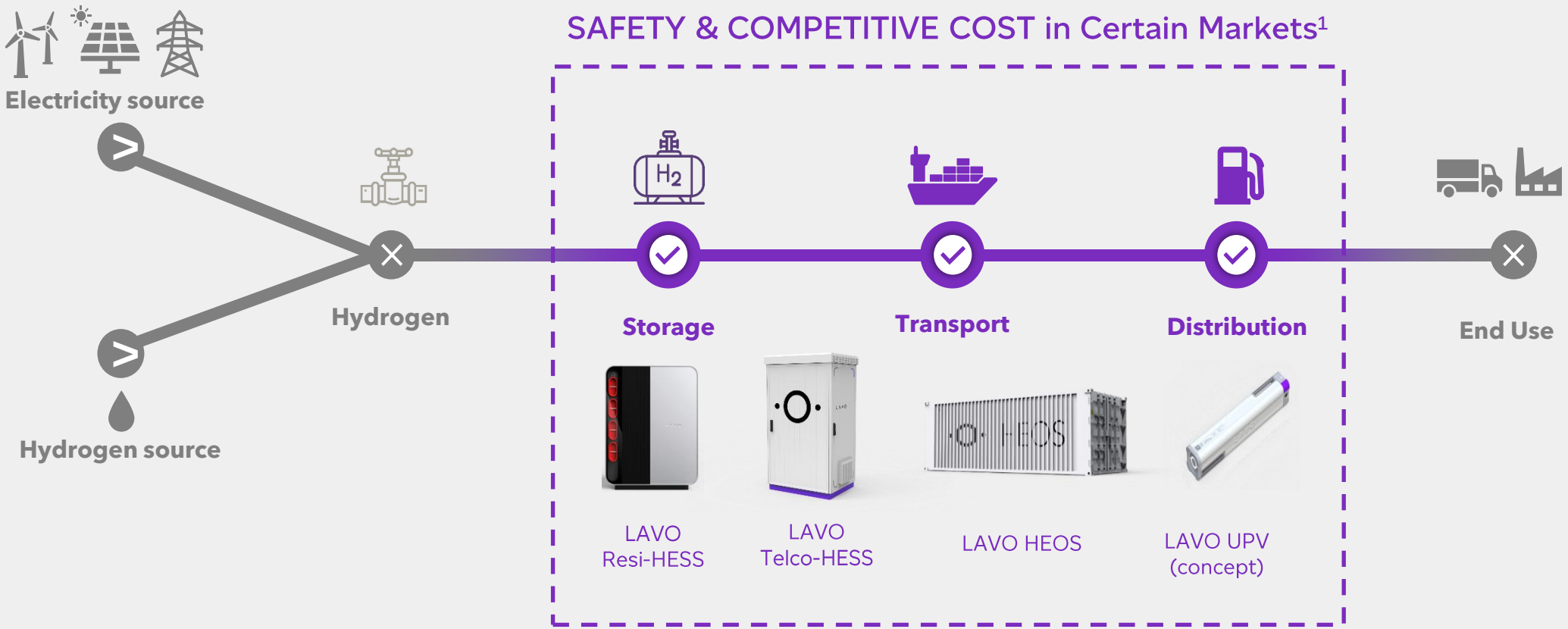
2024 Feb

- South Africa Telco Project in operation
- Set up LAVO Japan LLC

2024 Jun

- Development of G2 LAVO HESS for JP and other key markets
- Trial Projects globally in progress

LAVO Hydrogen Business Unit offers solutions to Hydrogen Storage, Transport and Distribution



LAVO Products with Metal Hydride hydrogen storage technology

Note 1: Whilst hydrogen will continue to compete with other technologies in the utility space – and the markets continue to mature – there are markets where hydrogen energy is feasible and viable now, with pathways to scale at speed.

A summary of LAVO Hydrogen Solutions

Targeted Sectors	LAVO Solution	Highlights
Residential Market Primary Target: Households in Australia and Japan		• Resi-HESS launched in 2020 & Japan version in 2024 . • *Energy Independence:* Provides the ability to go off-grid or significantly reduce reliance on the grid, particularly in areas with limited or unstable grid connectivity. • *Renewable Integration*: Seamlessly connects with renewable energy sources like solar maximizing the use of clean energy and reducing carbon footprints. • *Reliable Performance*: Ensures uninterrupted power supply, even in remote or grid-edge locations, enhancing energy security and resilience.
C&I Market Primary Target: Telco Tower in Africa, Australia, Southeast Asia & Saudi Arabia		• Telco-HESS launched in 2022. • *Replaces Diesel Generators in off-grid/bad grid sites*. • *Seamless Integration* with existing renewable energy sources (such as solar or wind) and on-site battery solutions • *A smaller footprint*, making it ideal for space-constrained locations. • Also adapt to Data Centre Market
Industry Market Primary Target: Hydrogen Exporting from Australia to Southeast Asia and Microgrid Solutions		• HEOS launched in 2022, • *Longevity*: Engineered to deliver *a life span of over 20 years* with zero degradation. • *Sustainability*: Fully recyclable and *free from toxic materials*. • *Safety and Efficiency*: Designed with safety as a top priority, HEOS enables the secure handling of hydrogen, even in densely populated urban environments.

LAVO has a unique hydrogen storage solution that utilizes Metal Hydride technology

Safe	✓ Low hazard at 3 Mpa pressure ✓ Regulated release rate ✓ Operates at ambient temperature ✓ Simplified installation and O&M
Economical	✓ Common alloy with no rare earth or precious metals ✓ Low material input costs ✓ Low footprint ✓ Lower cost of storage than alternatives
Reliable	✓ Negligible degradation (>20,000 cycles) ✓ No storage losses provides long term energy security
Modular	✓ Engineered to work seamlessly with proven components, including electrolyser, fuel cell and battery ✓ Flexible configuration and modularity provides scalability
Environmentally friendly	✓ No toxic materials ✓ Fully recyclable

LAVO Metal Hydride

- 2% wt capacity[1]
- 100kg of hydride can store up to 2kg of hydrogen

Modular Storage Solution

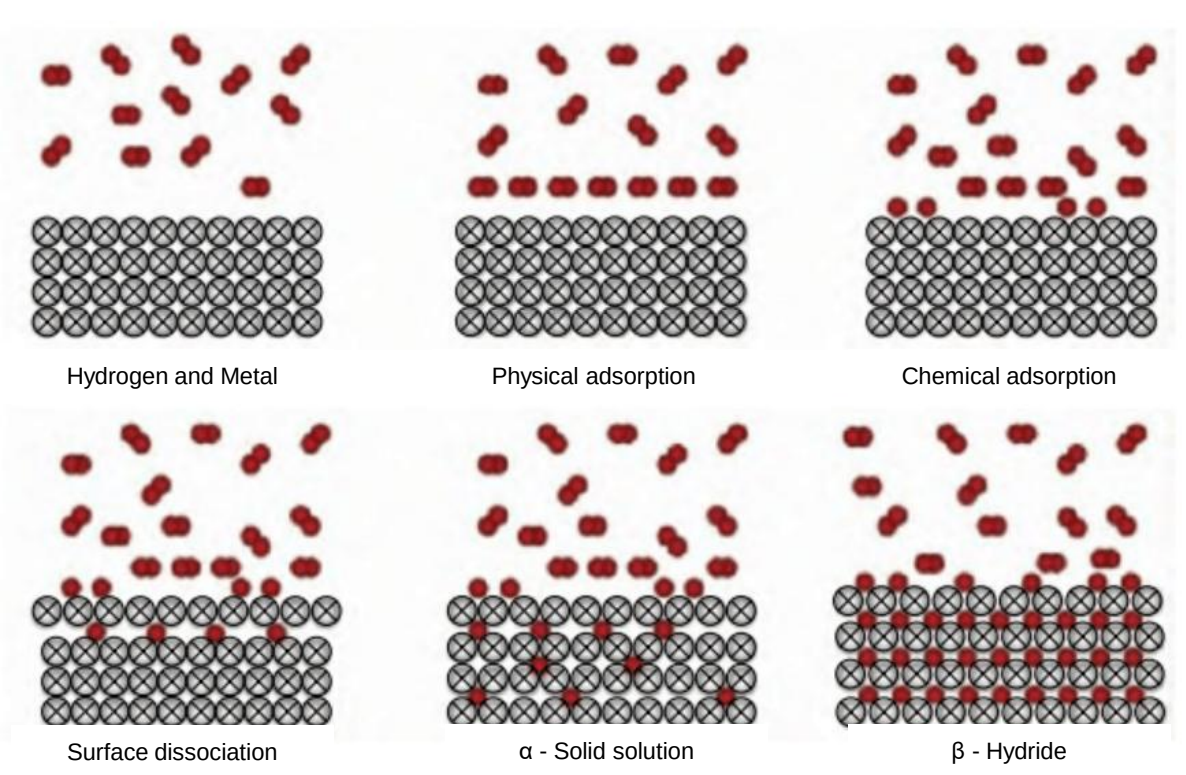
- Extendable & Stackable
- Customized based on customer requirements

LAVO's technology offers a superior solution to alternate long duration energy storage and Metal Hydride technologies

Notes 1: The percentage may change due to the actual use scenario

LAVO metal hydride acts as a SPONGE and absorb/desorb hydrogen at low pressure

The Mechanism of Metal Hydrogen Storage



The mechanism of solid metal Hydride (as shown in the pic) involves the following steps:

1. Hydrogen molecules physically adsorb on the surface of the metal or alloy.
2. Hydrogen molecules dissociate into hydrogen atoms on the surface of the metal or alloy.
3. Hydrogen atoms on the material's surface diffuse into the interior of the metal or alloy, forming a solid solution (α-phase).
4. Hydrogen atoms inside the material undergo chemical absorption with metal atoms, producing hydride (β-phase).

The volumetric hydrogen storage density of solid metal hydrogen storage is much higher than that of high-pressure gaseous hydrogen. LAVO MH tank at 3 MPa can store *20 times more that of large storage tanks* at 3 MPa, *4 times that of standard steel cylinders* at 15 MPa, and *2 times that of fiber-winding cylinders* at 35 MPa.

LAVO'S Patented Hydride Technology

	LAVO METAL HYDRIDE @ 30BAR	PRESSURISED HYDROGEN PATHWAY @ 700BAR	LIQUID HYDROGEN @-273 °C Cryogenic	THE AMMONIA PATHWAY	OTHER METAL HYDRIDES
SUSTAINABLE STORAGE SOLUTION	Metal alloys are non-toxic, 100% recyclable	High management and equipment cost	High management and equipment cost	Issues on Generating Hydrogen Back	Rare Metals, mass production and sustainability are issues
EFFICIENT STORAGE SOLUTION	20,000 charging or discharging cycles with very little capacity degradation	N/A	30% Lost In Transport	Low Efficiency	1,000 charging/discharging cycles
ENERGY DENSITY	5.8 MJ/L	4.6MJ/L	8.0MJ/L	15.6MJ/L	Varies based on composition
PRESSURE APPLICATION	30 ~ 200 Bar	700 Bar	N/A	N/A	Varies based on composition
SAFETY	• Low Pressure • Room Temperature • Metal self-regulates the rate of H_2 release	• Safety Issues with High pressure • Ambient Temperature with no heat management required	• Safety Issues with Cryogenic temperature • Losses in system during storage and transport	• Safety Issues with toxicity • Conversion required from H_2 to Ammonia and vice-versa.	Requires extra heat up to 350^{0}C to release hydrogen, e.g. magnesium-based

LAVO's Metal Hydride offers an Intrinsically Safe Solution

Metal hydrides offer several safety advantages for storing hydrogen compared to other methods:

- **Lower pressure**: Unlike compressed hydrogen which requires high-pressure tanks, metal hydrides bind hydrogen at near-ambient pressures. This reduces the risk of leaks and catastrophic ruptures in case of an accident.
- **Temperature control**: Hydrogen release from metal hydrides is influenced by temperature. They only release hydrogen when heated, adding a layer of control. Even if the container is damaged, the hydrogen won't explosively escape.
- **Chemical bonding**: In contrast to compressed hydrogen where the gas is physically trapped, metal hydrides form a chemical bond with hydrogen. This makes it more difficult for the hydrogen to leak out unintentionally.
- **Minimal evaporation**: Unlike liquid hydrogen which boils off at very low temperatures, metal hydrides experiences no hydrogen loss due to evaporation.

Overall, these factors make metal hydrides a safer option for handling and storing hydrogen, especially in portable applications.

Ref: https://www.youtube.com/watch?v=QiD7thxC9UQ&t=4s

LAVO Hydrogen Products & Use Case

LAVO HESS is launched with +2,000 pre-orders received

LAVO | HESS acts as a *SOLAR SPONGE*, integrating with solar to capture and store renewable energy for use when needed.

- Acts as the primary energy source for a household allowing it to utilise significant amounts of green energy for multiple uses including 24-hour house/pool heating, EV vehicle charging etc.
- Ability to go Off Grid Or reduce reliance on grid in areas which are on the edge of the grid.
- Maximise Energy Arbitrage by estimating demand/ solar irradiance, driving when to use LAVO to store / draw energy, improving peak shaves.
- Promote Green Energy Use such as replacing gas applications or EV charging, by reducing the marginal cost of electricity through LAVO.

Output 40kWh

- Integrated system including hydrogen production, storage, and power generation
- Metal Alloy has a lifespan up to 30 years.
- Size - 1.7 x 1.2 x 0.4m

International Awards

reddot winner 2022
best of the best

GOLD AWARD 2022

GOOD DESIGN AWARD® BEST IN CLASS

GOOD DESIGN AWARD® GOLD WINNER

GOOD DESIGN AWARD® MICHAEL BRYCE PATRON'S AWARD

Unveiling the R&D Journey of LAVO HESS

Metal Hydride at Lab scale

Metal Hydride at commercial production level

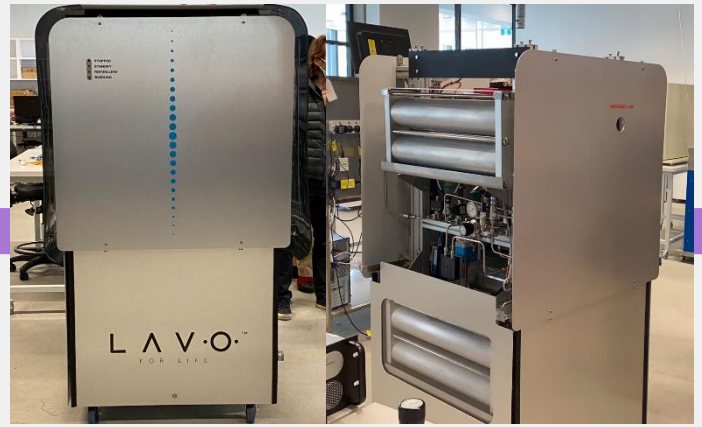
LAVO Vessels in HESS Unit and ready for activation

LAVO Vessels Prototype filled with Metal Hydride

LAVO HESS Pilot Product

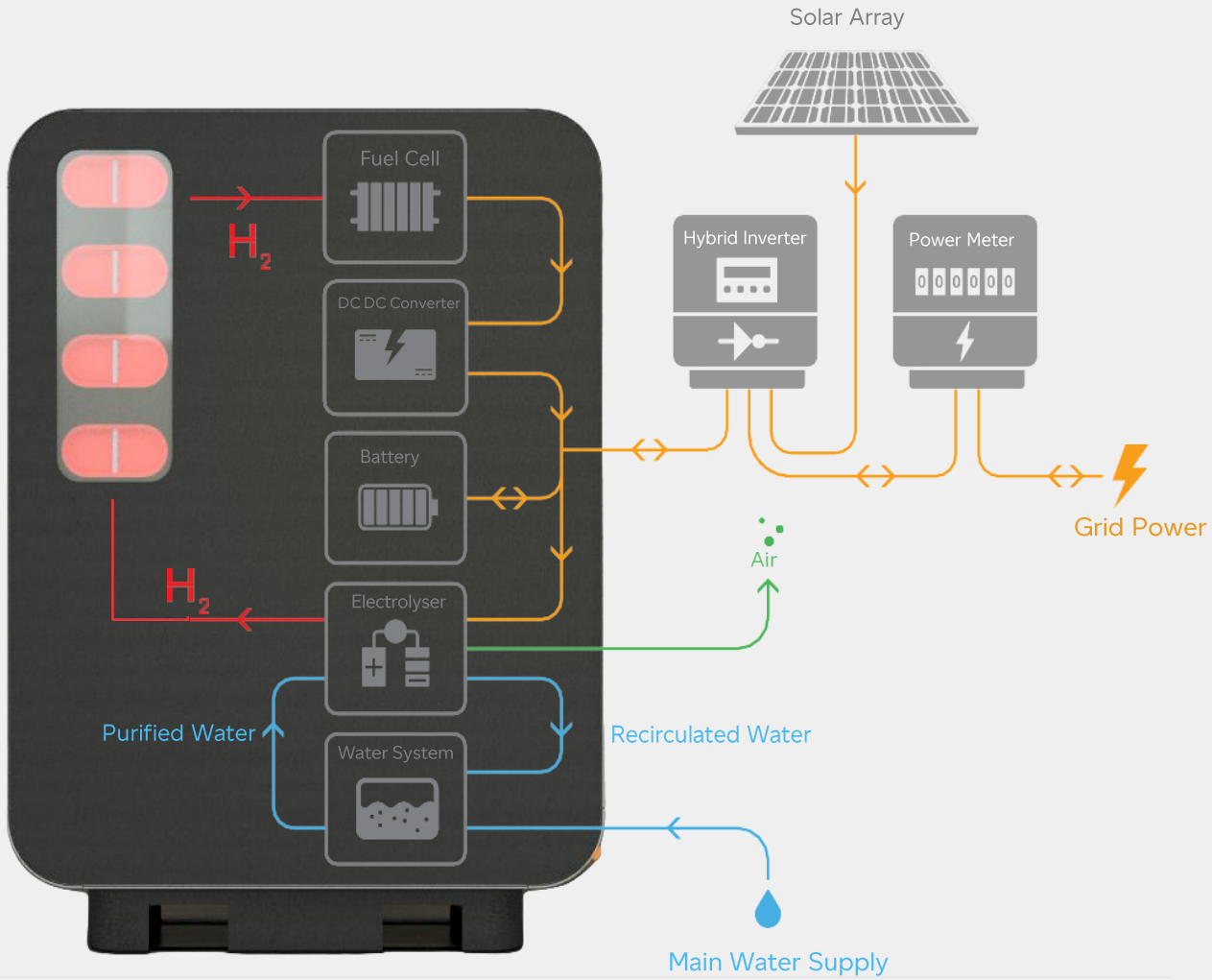
LAVO Alpha Prototype

LAVO Lab Prototype



LAVO HESS (JP ver.) is now customized for Japan Market

- **Creates Hydrogen** from water
- **Stores Hydrogen** into LAVO™'s patented metal hydride
- **Generates Electricity** by converting hydrogen into power
- **Safety Controls** safety controls integrated within the system for over-pressure or fire event
- **Integrates** with fuel cells and electrolysers without the need of compressors



LAVO HESS (JP ver.) Specs

Parameter	Value
Dimensions (HxWxD)	1785 x 1333 x 563 mm
Weight (incl. Vessels)	600 kg
Hydride Vessels	4 Vessels
Max System Pressure	< 10 barg
Vessel Weight	21 kg per Vessel
Mounting[1]	Floor Mount/Outdoors
Nominal Voltage	51.2 V
Recommended Temperature	2° - 50° C
Environmental Humidity Range	0 to 95% RH
Maximum Elevation	2000 m
Noise Level	≤ 75 dbA @ 1 m distance
Enclosure Protection Rating	IP54
Storage Capacity	7000 NL
Water Supply	Standard Residential Portable Water

Residential Market for LAVO HESS

LAVO primarily targets on high-net-worth early adopter family who are looking for independent and reliable power supply.

70% –households willing to switch **to clean energy providers.**

2% – Australians live **off-grid,** primarily in remote and rural areas. However, these areas account for over 6% of **the nation's total electricity consumption.**

56% –Projected **increase in electricity costs** over the next two years.

Remote and rural areas face significantly higher electricity prices, driven by:

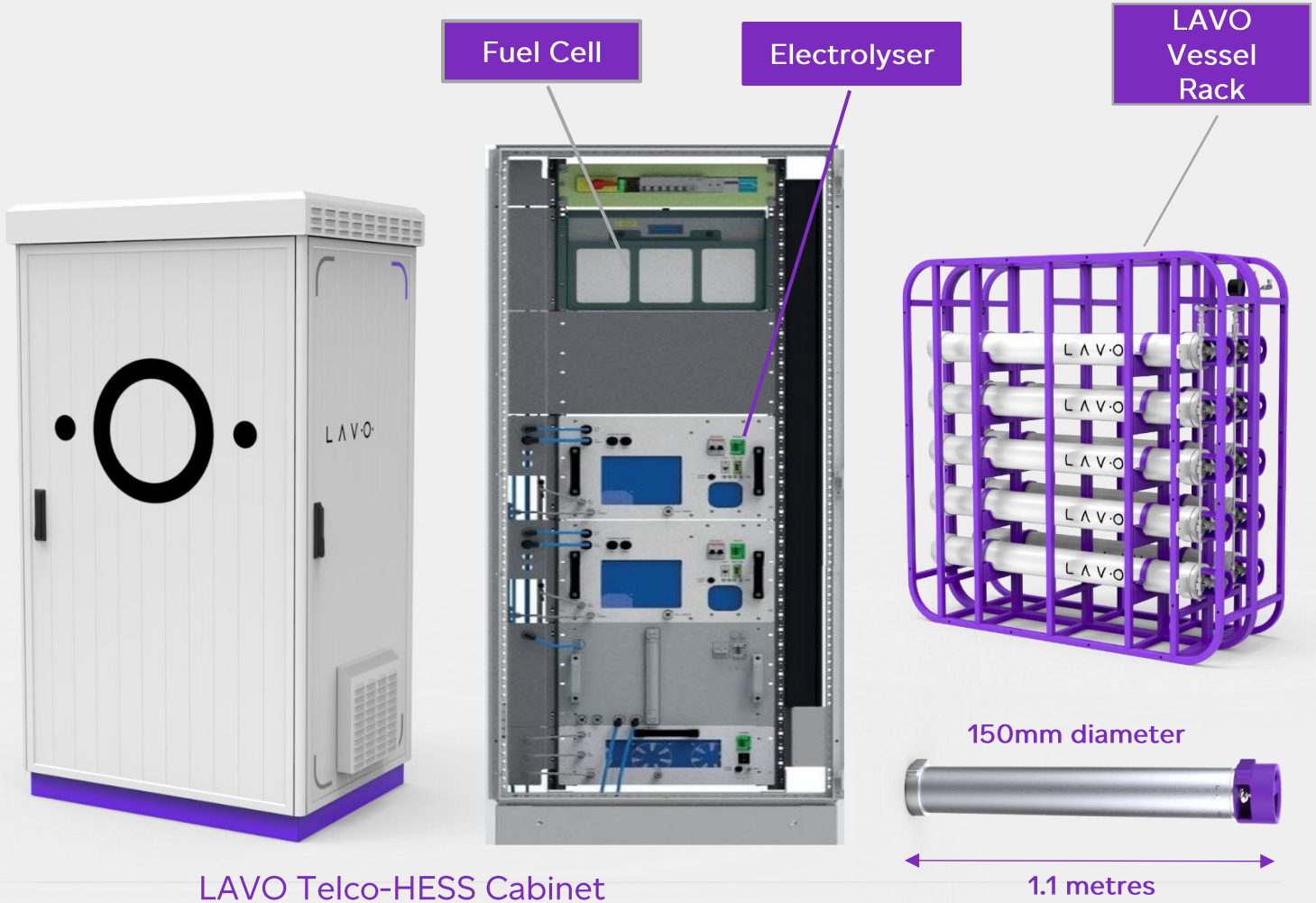
- High fuel costs for local power generation (diesel or natural gas).
- Additional expenses for transporting fuel via truck or ship.
- The need to store fuel reserves on-site to mitigate supply risks during extreme weather or unexpected demand surges.

25% –say energy bills their most stressful expense.

Source: 2https://reneweconomy.com.au 4Australian Financial Review, federal budget Oct-22 forecast energy prices. Australian Energy Market Operator (AEMO) has said that energy prices are expected to continue to rise in the coming years, due to several factors, including the closure of coal-fired power plants and the increasing cost of renewable energy. 5BloombergNEF. 5AEMO 2022 ISP. 7Australian Government Target, The International Energy Agency (IEA). 9Sustainability The New Megatrend, Nielsen, 2020. 102021 Subscription Economy Index(SEI), published by McKinsey & Company.10Australian Energy Market Commission (AEMC).

The launch of **LAVO Telco-HESS** unlocks opportunities in **Telecommunication tower sites and data centers**

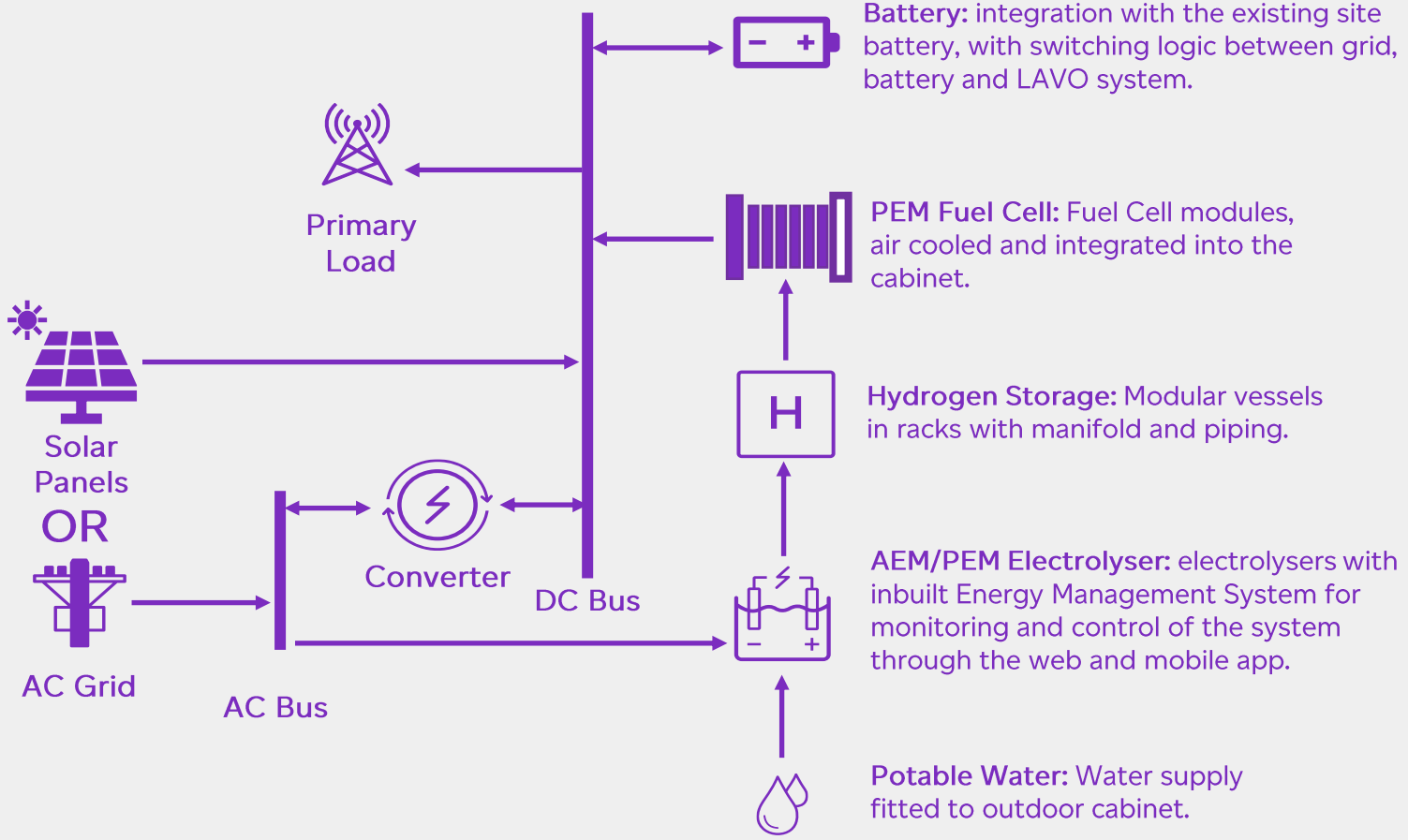
- Based on the design of LAVO Resi- HESS, LAVO Telco-HESS is the 2nd generation of LAVO Hydrogen Energy Storage System in smaller scale.
- LAVO Telco-HESS integrates:
  - Electrolyser
  - LAVO Vessels filled with LAVO's patent metal Hydride
  - Fuel cells
  - Water purification systems
  - Control systems
- Provides reliable power supply for telecommunication towers in off-grid and bad grid situation
- Features a flexible modular design for easily adjusting the modules to meet various power needs.
- Unit price varies depending on the system specifications.



LAVO Telco-HESS Cabinet

LAVO Telco-HESS System Diagram and Specs

Parameter	Figure
Site power load	2kW- 20kW
Maintenance Frequency	Once a year
Hydrogen storage capacity	56.3 kWh – 225.3 kWh (expandable)
Rated power of hydrogen production electrolyser	2kW – 40kW
Rated power of fuel cell	2kW – 20kW
IP Rating	IP20
Dimension of One Cabinet (W x D x H)	800 x 1000 x 1900 mm
Ambient Temp Range	5° ~ 40° C



LAVO Telco-HESS – Replacing Deisel Gensets in Telco Industry

Transitioning from diesel requires innovative, cost-effective solutions balancing reliability, sustainability, and economic feasibility.

Importance of reliable energy supply

- Global Footprint: Over **5 million** telecom towers worldwide.
- Telecommunications services demand **high availability and reliability** – among the most stringent globally.
- Consumer and carrier expectations drive **constant, uninterrupted** service.

Current Power Solution

- Primary Power: Grid or onsite renewable energy.
- Backup Systems: Batteries and/or **diesel generators**.
- Site-Specific Configurations: Grid absence often leads to *diesel as the primary power source*.

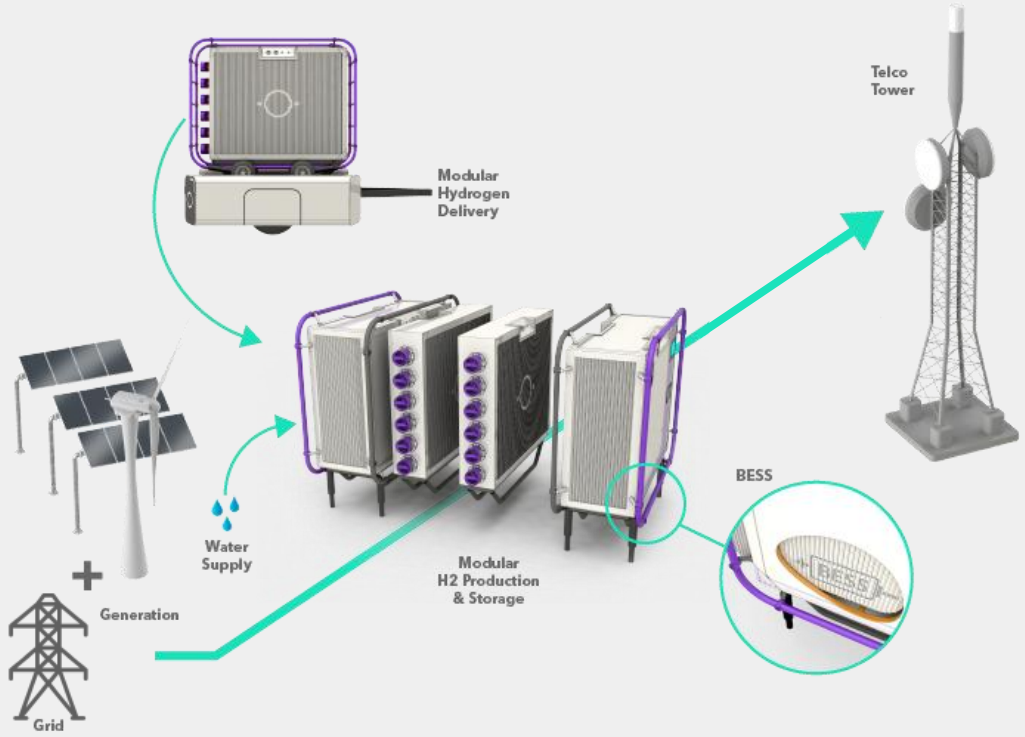
Issues of Diesel Gensets

- High operating costs: 3.5 billion litres annually diesel consumption plus fuel theft and maintenance costs
- High Emissions : Contribute 2% of global carbon emissions – equal to the aviation industry.
- Noise pollution
- Reliability **issues:** lack of real-time monitoring system

Existing Alternatives and Challenges:

- **Batteries:** Suitable for short-term outages but degrade quickly, limiting long-term reliability.
- **Fuel Cells:**
  - **Methanol/Ammonia** needed to be delivered to site and stored in large tanks..
  - **Hydrogen gas** often requires very large tanks or require significant compression on site.
- **Cost Barriers:** High upfront costs and long payback periods deter investment.
- **Operational Constraints:** Long-term contracts with limited cost recovery options.

LAVO Telco-HESS provides a reliable power supply for a range of applications



On-grid backup	Bad grid	Off-grid
Scalable storage and power capacity		

LAVO HESS solution with lower emissions, reduced maintenance and low LCOE		
	Diesel	**LAVO HESS**
Reliability	~	✓
Long runtime	~	✓
Long asset life	~	✓
Low maintenance	✗	✓
Noise	✗	✓
Environmental	✗	✓
Total lifetime cost	✗	✓
Temperature range	✓	✓
Small footprint	✓	✓

Telco-HESS Case Study South Africa

Trial Project Brief

Electricity grid reliability problems and increasing instances of load shedding have led to increasing reliance on diesel generators across the Vodacom portfolio of telecommunication towers. This not only presents a significant barrier to Vodacom's target of 100% reduction in Scope 1 and 2 emissions by 2030, but it has also resulted in increasing capital expenditure on diesel generators and increasing operating expenditure on fuel and maintenance.

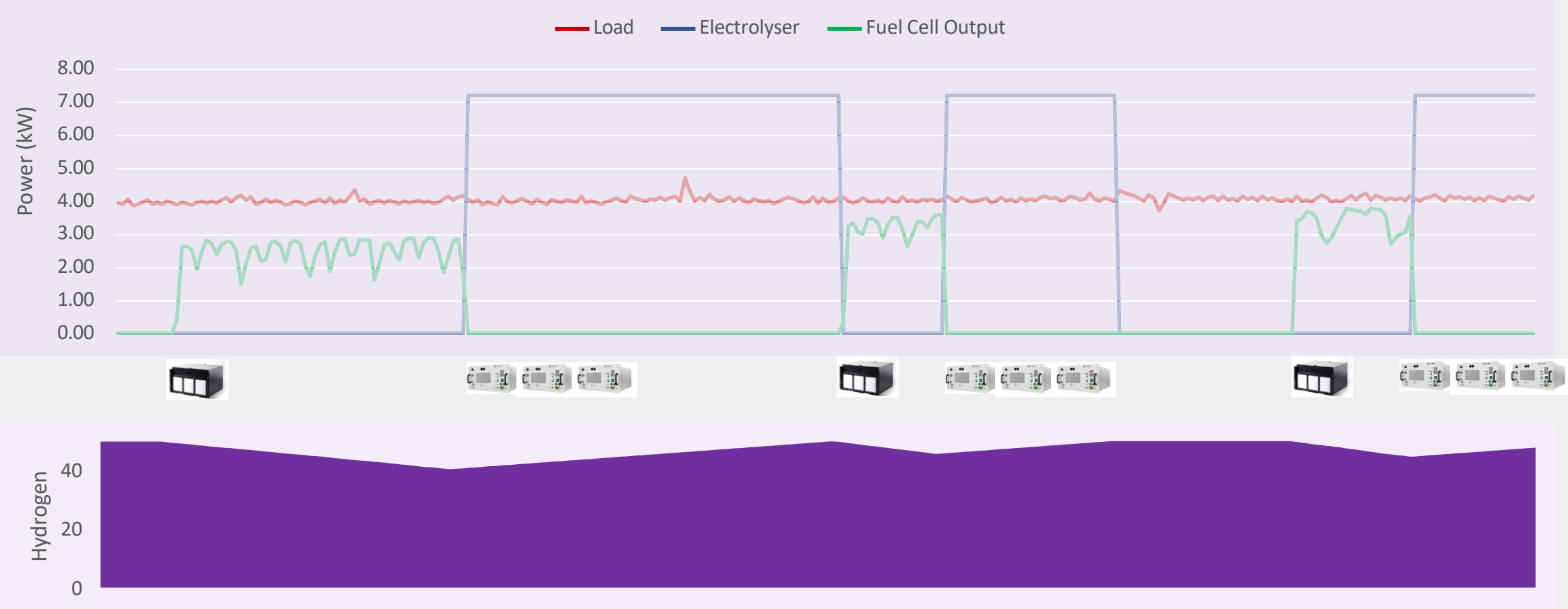
Vodacom entered into a trial agreement with LAVO in September 2023 to evaluate whether a self-refuelling, hydrogen powered fuel cell system (LAVO Telco-HESS) is suitable as a low carbon energy replacement for diesel generators as a backup power supply during outages and load shedding instances in South Africa. Further, Vodacom issued a Letter of Intent to LAVO indicating a scaled deployment of 6,134 LAVO Hydrogen Storage Systems across Vodacom's network over 5 years.

LAVO system was commissioned in February 2024 has seamlessly replaced the diesel generator for the past three months, ensuring uninterrupted power supply. It demonstrated its reliability by efficiently energizing the Telco Tower throughout an 18-hour electricity outage. The Trial has been running for 12 months till now.

Vodacom and LAVO have agreed to form a strategic partnership aimed at expanding commercial collaboration and accelerating the widespread adoption of the LAVO system throughout Africa.

Snap shot of System modes of operation

The system reacts to changes in the SoC of the battery



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LAVO HEOS a deployable, safe and scalable hydrogen end-to-end transport & distribution solution

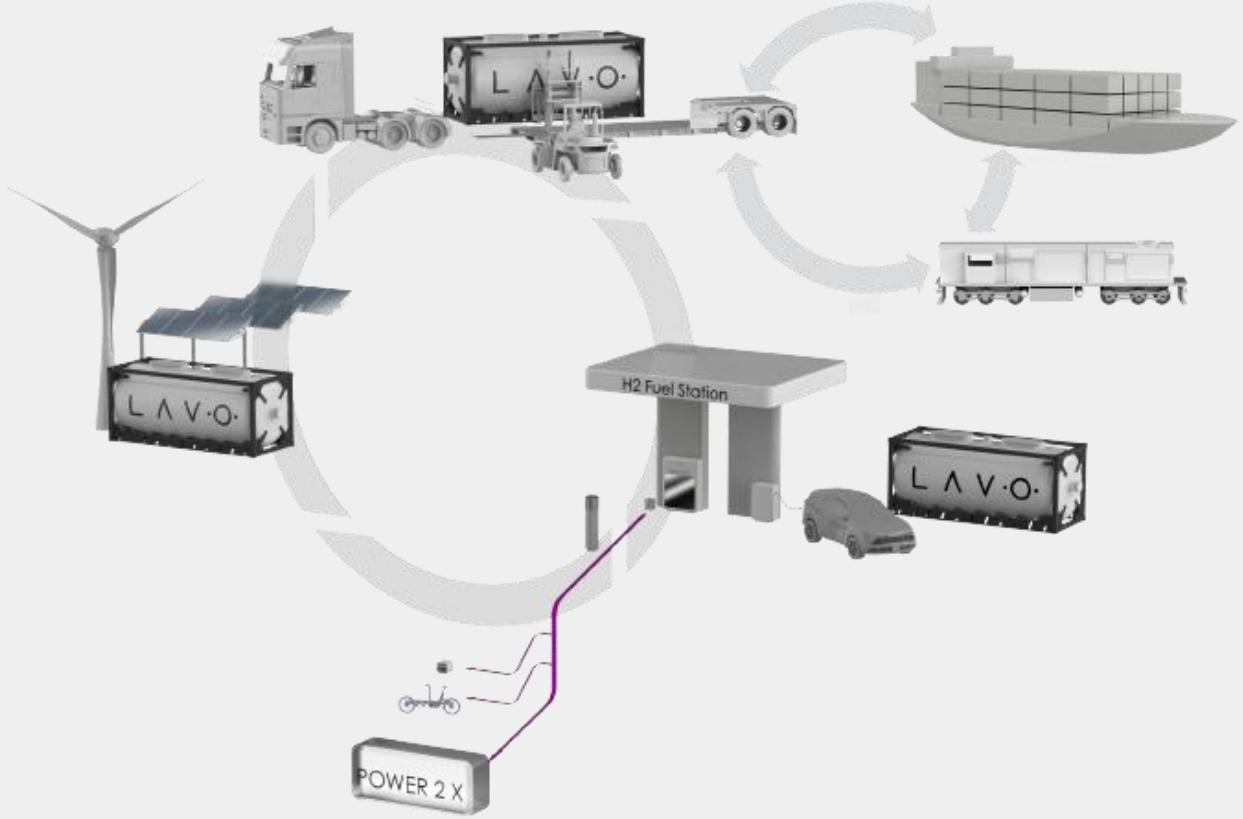
LAVO HEOS introduction

- Scalable from single vessel up to 12 vessels (4 vessels/rack*3 racks) plus pipes and valves; .
- Can store 1.1-1.2 tons of hydrogen in a 40-foot container volume.
- Charging, discharging, and storing hydrogen at low pressure and room temperature.
- The stored hydrogen energy is equivalent to approximately 28 MWH.

LAVO HEOS Specs

Parameters	Figures
Single Tube Alloy Weight	5,208 kg/single tube
Single Tube Total Weight	7,960 kg/single tube
Single Tube Length	11,271mm
Total hydrogen storage capacity	840 kg for 12 vessels at 3 Mpa-g
Design working environment	-50 ℃ to 220 ℃

Use case 1 - LAVO HEOS enables stationary H2 storage and Export



- **Create Hydrogen** from green energy or ‘green grid’
- **Store Hydrogen** in a LAVO HEOS container in a solid state
- **Transport hydrogen** via existing road or rail infrastructure given inherently safe in a solid state
- **Export hydrogen** into overseas markets via container vessel
- **Harness Hydrogen** for refuelling or other industrial applications (Power-to-X)
- **Democratise hydrogen,** through LAVO’s Universal Portable Vessel (UPV) for end user applications

H2 transport via HEOS units is intrinsically safe and convenient

	LAVO HEOS	Compressed H_2	Liquid H_2	Ammonia
Ship availability	Normal container ship ●	Design concept only ○	One pilot ship only ◔	Limited availability ◑
Port handling	Convenient via existing container loading terminals ●	Requires transfer to a distribution system / storage ◔	Requires transfer to a distribution system / storage ◔	Requires cracking to hydrogen, transfer / storage ◔
Transport efficiency	No boil-off gas, containers fully recyclable ●	High boil-off gas renders it unsuitable for long distances ○	Energy intensive handling at ports ◑	Efficiency losses during cracking and compression ◑
Safety and environment	Intrinsically safe and self regulating if any leak ●	Rapid release and explosion hazard in case of leak ◔	Burn hazard and low Lower Explosive Limit ◔	Toxic and a pollutant with noxious gas by-products ◑

Legend: ○ Denotes attractiveness

World-first Solid-State Green H2 Shipment on a standard commercial container ship

Shipping of solid-state Green Hydrogen trial underway

- LAVO was successful delivered 20ft standard shipping container with built-in / affixed DN150 vessel filled with the LAVO hydrogen absorption metal alloys in Q3 2023. Hydrogen capacity is 3.5 – 4kg (proof of concept).
- LAVO has received IMDG approval for hydrogen transport by sea

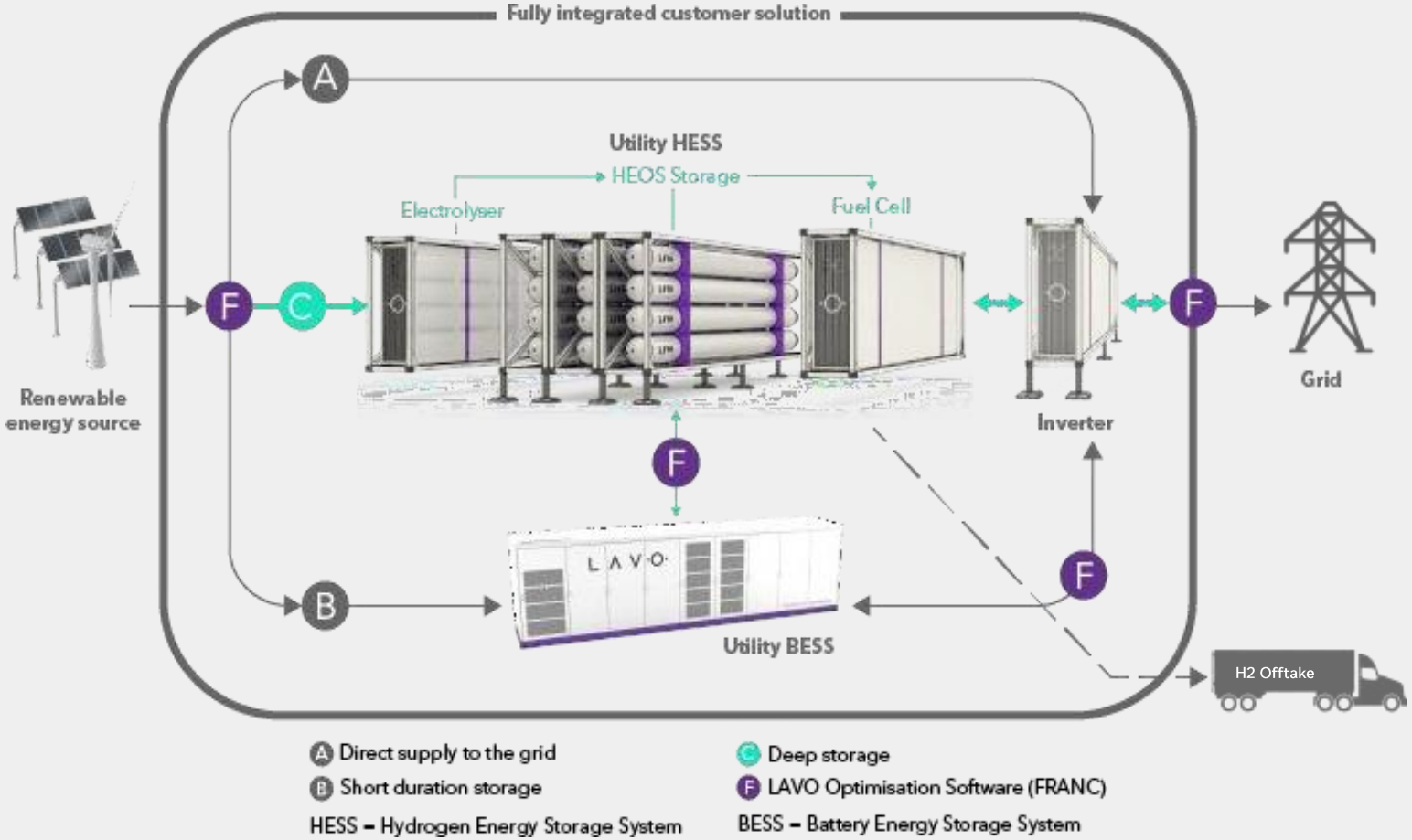
Marubeni

Ministry of the Environment
Government of Japan
Pilot project for comprehensive support throughout the whole hydrogen supply chain abroad (2022)

Green hydrogen to be exported to Indonesia; and the broader Indo-Pacific region in future

[1] International Maritime Dangerous Goods (IMDG) Code

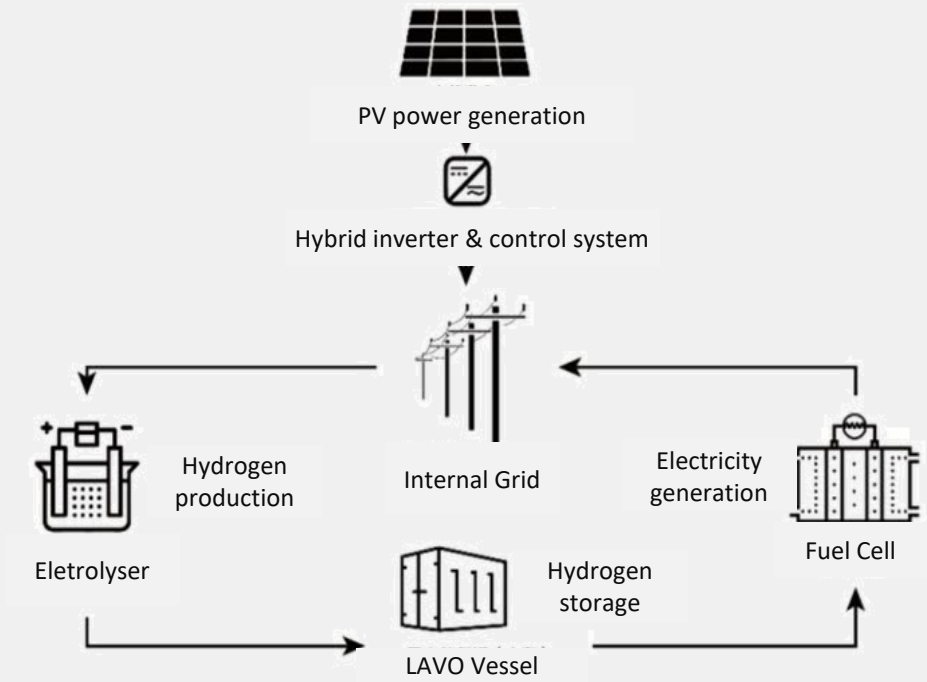
Use case 2 – LAVO Utility HESS enables microgrid solution



- **Microgrids:** Australia is well suited to microgrid deployment due to sparse populations located at the end of long electricity network infrastructure.
- Over 200 microgrids already operate in Australia and the potential for many more is becoming economically attractive as costs for supply to loads at the fringe of the grid outweigh revenues available.
- Most microgrids currently rely upon diesel generation when in island mode to firm the renewable and battery storage components. Hydrogen storage is a cleaner, more cost-efficient option for this role.

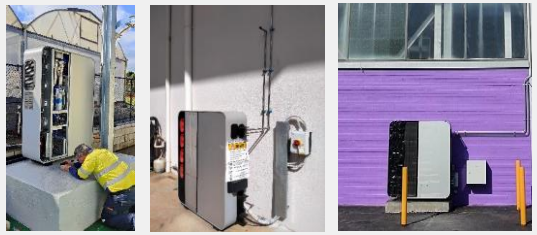
The completion of LAVO HEOS Demo Site in Q3 2023

The single hydrogen can release up to 82 kilograms of Hydrogen, providing a maximum power generation capacity of 1271 kWh (DC-DC output) for continuous operation of a fuel cell in one cycle. In the future, with upgrades to the hydrogen storage alloy formula, adjustments to loading density, and optimization of the thermal management system, the maximum hydrogen storage capacity per unit is expected to reach 100 kilograms.



LAVO Hydrogen Demonstration Sites

- Deployment of LAVO HESS in Coregas in South Australia



- Deployment of LAVO HESS in WA (Hybrid Systems), QLD (QUT), VIC (CSIRO) and China (Little Duck)

- Deployment of large-scale hydrogen storage containers and electrolysers for power plants
- Completion of comprehensive LAVO HEOS integration testing with Tongyu, China

- Completion of LAVO HEOS Demo Project in Shandong, China
- Completion of Telco Project

2021

- Large-scale absorption / desorption feasibility testing with Coregas & Tong Yu

Early 2022

Mid 2022

- 3x LAVO HESS Demo Deployment under Stand-Alone Power System in Gigarre Solar Power Station in VIC

Late 2022

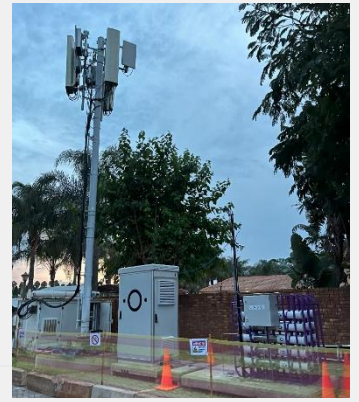
Early 2023

- Start Marubeni Project
- Start Telco Tower Trial Project

Mid 2023

Late 2023

- Completion of Marubeni Project



Early 2024

LAVO

LAVO offers great flexibility in capability potentials

LAVO's hydrogen solution can scale from kilowatt (kW) to megawatt (MW) capacities, making it suitable for residential, commercial and industrial (C&I), and utility customers.

LAVO Metal Hydride (Per Vessel)	13 kg MH with 170g H2 (5.6kwh) 	26kg MH with 338g H2 (11.3kwh) 	[.....]	5,208kg MH with 67.7kg H2 (2.3Mwh) 
Electrolyser (Per Unit)	2.4kw AEM EL 	5kw - 10kw PEM EL 	[.....]	1MW PEM EL 
PEM Fuel Cell (Per Unit)	4kw FC 	5kw - 10kw FC 	[.....]	Horizon 1MW FC 

LAVO builds up Global Partners to support solution delivery

Existing Suppliers & Potential suppliers

Nedstack PEM FUEL CELLS
Horizon Fuel Cell Technologies
Enapter
H2 中电丰业 SinoHy Energy
H2 CoreSystems
Intelligent Energy
Swagelok
BALLARD™

Grants & funding

Australian Government
AMGC ADVANCED MANUFACTURING GROWTH CENTRE LTD
NSW

LAVO FOR LIFE

Development partners

THE UNIVERSITY OF NEWCASTLE AUSTRALIA
UNSW AUSTRALIA
東京大学 THE UNIVERSITY OF TOKYO
KAUST Destination Deep Tech

Manufacturing partners and service providers

AMPCONTROL®
FORT WAYNE METALS
VARLEY EXCELLENCE SINCE 1886
通裕重工 TONGYU HEAVY INDUSTRY
GHD
LEWEI

Global Customers

Marubeni
vodacom


LAVO
FOR LIFE