

**FUTURE MOBILITY
DAY #4**

8 June 2023




www.portkemblahydrogenhub.com.au

H2 Future Mobility Day #4 Program

- 8 June 2023

1. Turn off your camera please
2. We will send out a copy of the slide deck to all participants
3. Put any questions you may have in the Chat, we will pick them up from there

The page is framed by a colorful Aboriginal-style border. The top left shows a dark night sky with stars, a crescent moon, and a sun. The middle left depicts a brown and orange landscape with emus and kangaroos. The bottom left shows a blue river with a fish. The right side features a blue and green ocean with a whale. The border is decorated with white dotted lines.

The Department of Regional New South Wales acknowledges that it stands on Country which always was and always will be Aboriginal land. We acknowledge the Traditional Custodians of the land and waters, and we show our respect for Elders past, present and emerging. We are committed to providing places in which Aboriginal people are included socially, culturally and economically through thoughtful and collaborative approaches to our work.

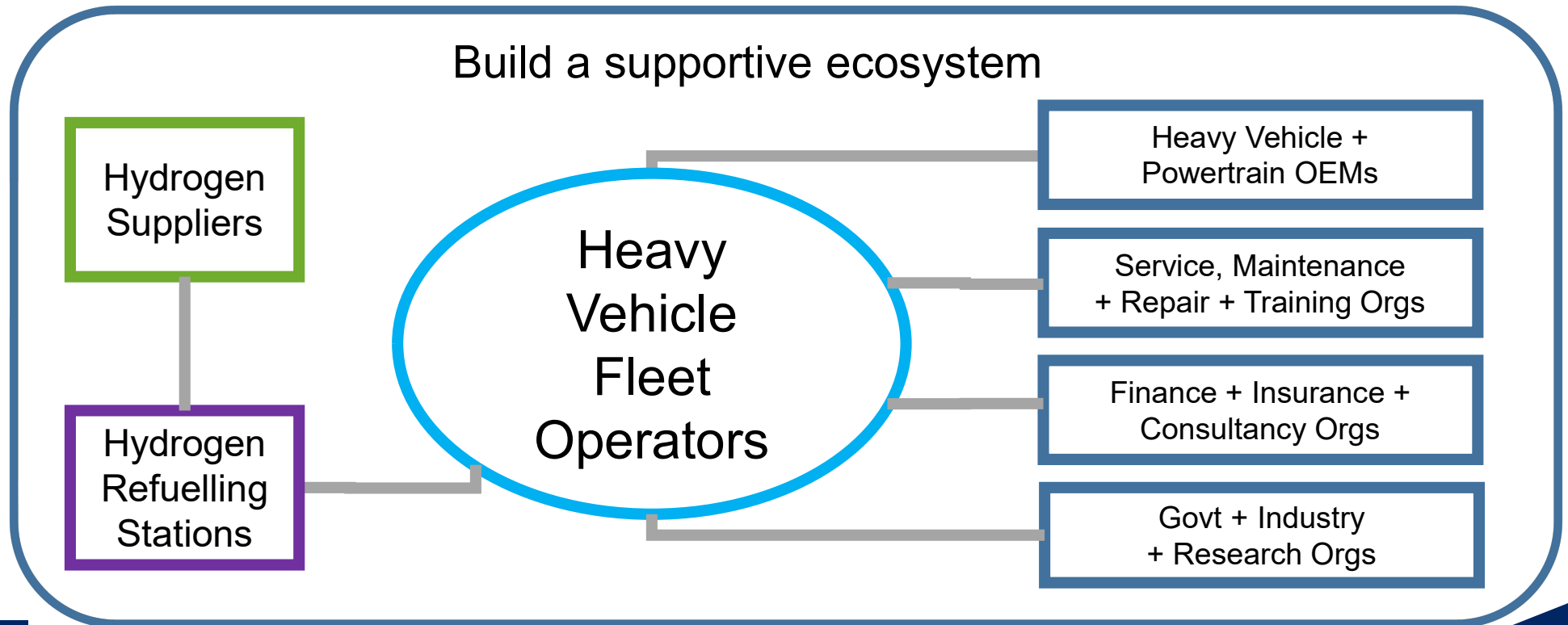
H2 Future Mobility Day #4 Program

- 8 June 2023

11.00am	Welcome	Nigel McKinnon Dept of Regional NSW
11.05am	Refuelling Infrastructure	Nathan Pearce-Boltec BOC
11.15am	FCEV TS Prime Mover	Ben Kiddle HDrive
11.25am	Hydrogen-Diesel Hybrid Conversion	Stuart Pratt Wasco
11.35pm	FCEV Refuse Truck Trial	Chris Wade Remondis
11.45pm	H2ICE – UNSW Engine Lab Technology	Shawn Kook UNSW
11.55pm	Q & A	

Initiative #1: Establish H2 Future Mobility Cluster

Heavy Vehicle Fleet Operators are the **core members** of the **Cluster**. Members also include a range of Heavy Vehicle and Powertrain OEMs, service, repair and training organisations, business and industry groups, finance and insurance providers, government, universities and research organisations. **Hydrogen Refuelling Station (HRS)** infrastructure is a **key enabler** supported by hydrogen suppliers.





**H2 TRAINING + SAFETY
DAY #2**

28 February 2023

Initiative #4: Enabling infrastructure

Develop a network of commercial hydrogen refuelling stations (HRS) to support the transition to hydrogen powered zero emissions vehicles

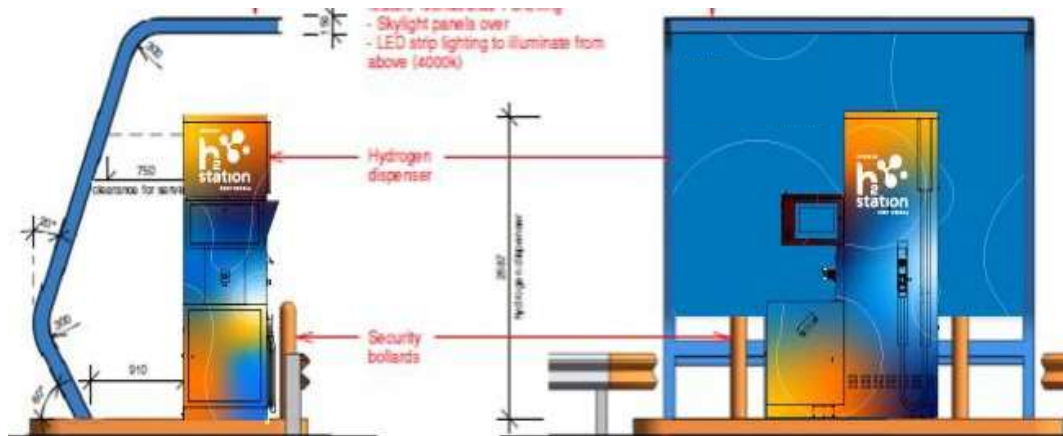
- public multi lane stations
- on-site private fleet refuellers
- mobile refuellers
- train refueller

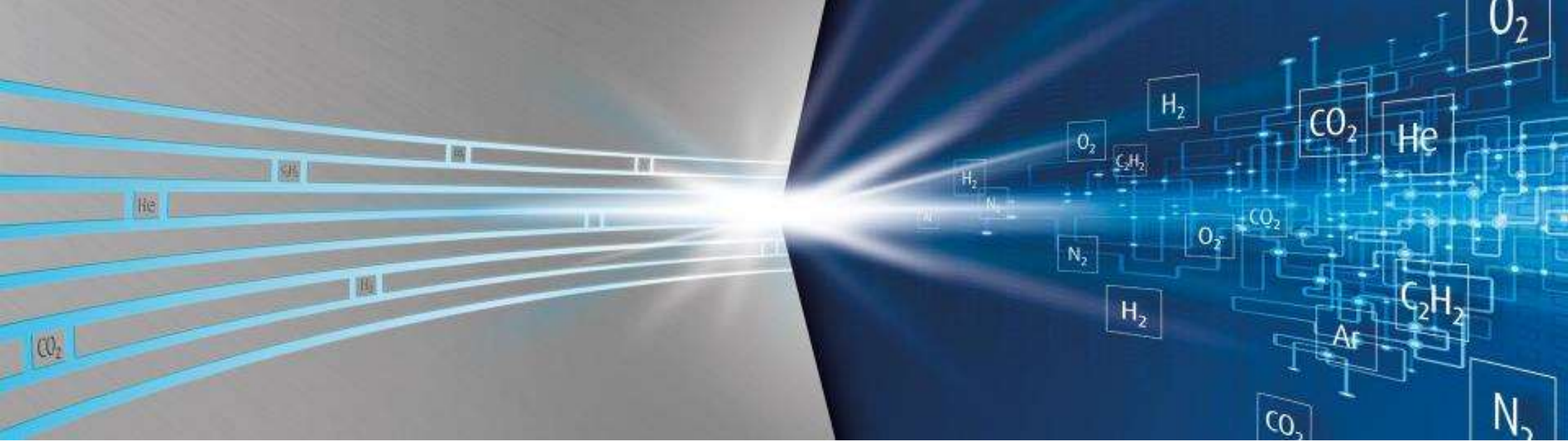


Coregas Hydrogen Refuelling Station (HRS)

Launch Milestones

- › 350 bar heavy vehicles refueller, up to 10 vehicles per day
- › Refuelling station commissioning in progress
- › Launch event with NSW Government in July





Illawarra Hydrogen Technology Hub

Technology & Project Update

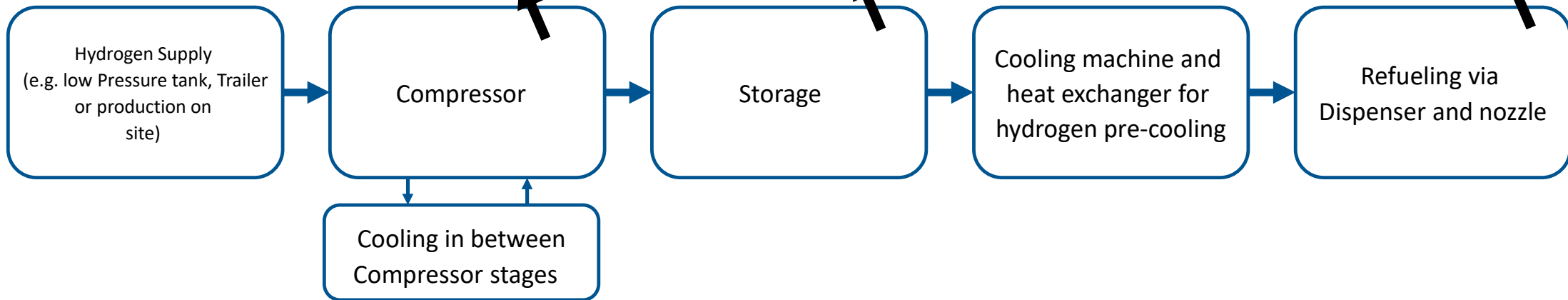
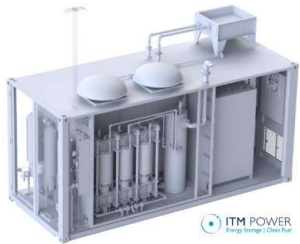


- Intro into Hydrogen Refuelling Stations (HRS)
- Project Update
- Logistics and Trucking HRS
- Public transport bus HRS



Introduction

What is a Hydrogen Refueling Station?



Project Update

Customer & Offtake Updates



The Illawarra Hydrogen Technology Hub will be the largest green hydrogen mobility project in the Southern Hemisphere

The NSW Government has committed \$28.5m to the BOC Hydrogen Hub Project

Phase 1 will include:

- 30 buses
- 10 trucks
- Up to 5 HRS units both regionally and in Sydney to support the Hume Hydrogen Highway initiative
- Electrolyser production of 4 tonnes per day of green hydrogen
- Supporting emerging energy sectors in the region and conventional hydrogen users

ARENA are looking to support truck and bus users with further funding to support diesel parity on TCO for early adopters

FEED Study

- BOC has commenced the FEED study for the Port Kembla Hub
- BOC are expecting to achieve FID in Q4 2023

Logistics and Trucking HRS

A new entrant to the Australian Market

THE LINDE GROUP

Linde

BOC is working with a European OEM to bring 10 FCEV trucks to Wollongong

Trucks and infrastructure will meet all Australian Standards based on BOC and OEM experience in Australia and internationally – term sheets with multiple regional providers

Truck Specifications (Prime Movers)

- Range: ~700km
- Tank Size: ~70kg
- Pressure: 700 bar
- Trained dealer network to ensure after sales support

HRS Unit Port Kembla

- Refuelling time: ~20 minutes
- Refuel 10 trucks per day (scalable over time)
- Further HRS units are planned for Western Sydney



Public Transport Bus HRS

Leveraging Global Experience Locally

THE LINDE GROUP

Linde

BOC is working with Foton Mobility to bring 30 FCEV buses to Australia in phase one of this project – Foton have deployed 000's of FCEV vehicles internationally

Bus and infrastructure will meet all Australian Standards based on BOC and OEM experience in Australia and internationally

Bus Specifications

- Fuel Efficiency: ~6.9kg/100km
- Tank Size: ~30kg
- Pressure: 350 bar
- Trained dealer network to ensure after sales support as well as local manufacturing content

HRS Units

- Refuelling time: ~20 minutes
- Refuel 10-20 buses per day (scalable over time)



How can you participate?

The Illawarra Hydrogen Technology Hub enables the ongoing decarbonisation of the Wollongong Region

The project will create new local jobs as well as building skills in the important decarbonisation sector

For more information or to participate contact chris.dolman@boc.com





HDrive – Driving a Greener Future

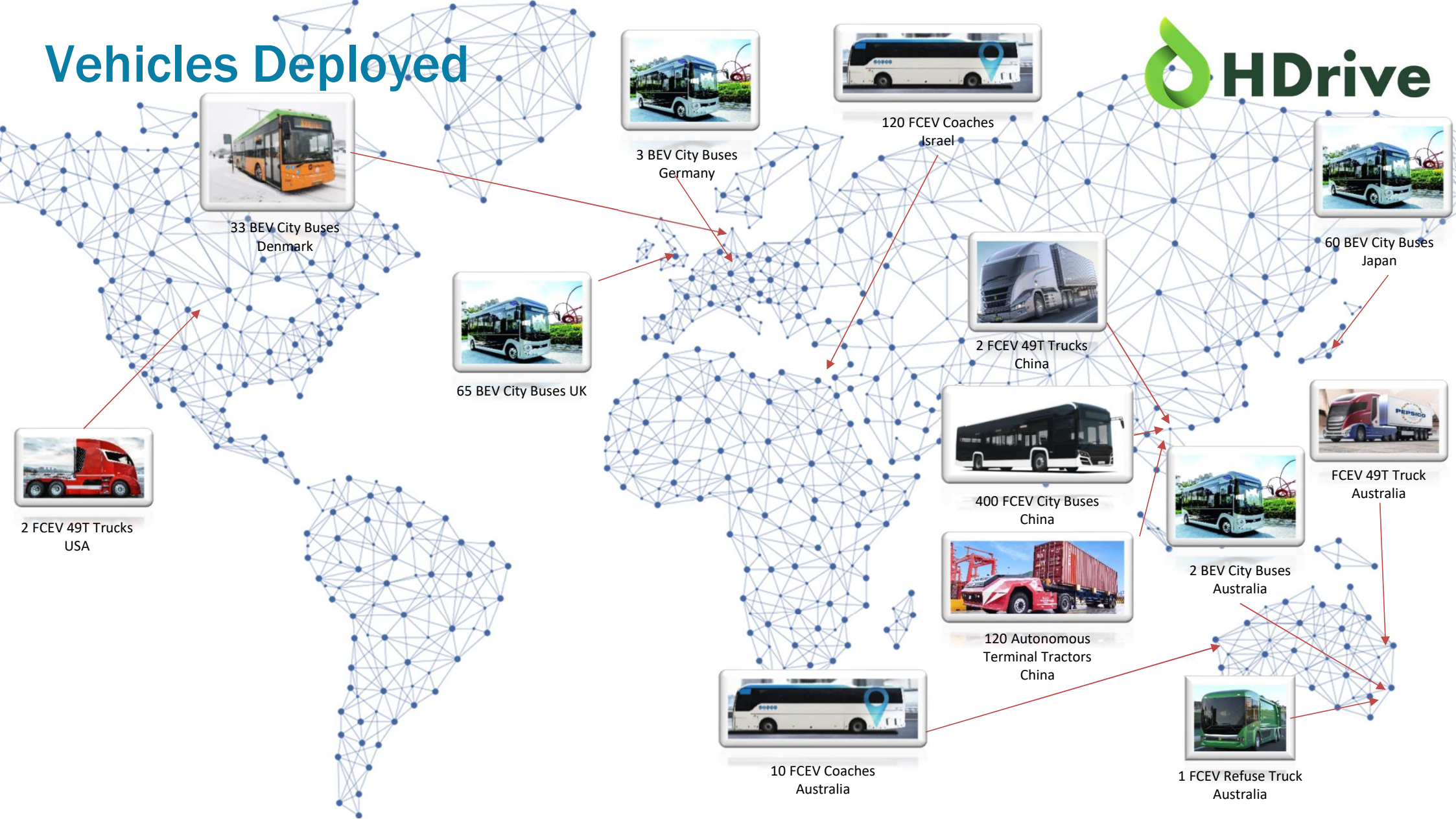
HDrive Hydrogen Truck Range



HDrive Hydrogen Bus Range



Vehicles Deployed



33 BEV City Buses
Denmark

3 BEV City Buses
Germany

120 FCEV Coaches
Israel

60 BEV City Buses
Japan

65 BEV City Buses
UK

2 FCEV 49T Trucks
China

400 FCEV City Buses
China

FCEV 49T Truck
Australia

2 FCEV 49T Trucks
USA

120 Autonomous
Terminal Tractors
China

2 BEV City Buses
Australia

10 FCEV Coaches
Australia

1 FCEV Refuse Truck
Australia

PepsiCo TS18-110



TS18-110
110kW Ballard FC Move Fuel Cell Product
18T GCM rated on a 50T base – Why?
Customer requirements
Price Base

Coming Soon – TD23-160DE



TG23-160DE
160kW Ballard Fuel Cell Product
23T Refuse truck – Dennis Eagle Elite 2 Glider re-power
Customer requirements
Price Base

Coming Soon – Vehicles in Build



HP70-400 – 70T B-double Rated Prime Mover

FC120 – 12.5m Low Floor City Bus

T30-200 – 30T 8x4 Cement Agitator Truck

FV75 – 7.5m Mini Bus

TS50-300 – 50T Prime Mover

"If you build it, they will come."
-Field of Dreams (1989)





Hydrogen – Diesel Hybrid Conversion and Demonstration

8th June 2023 – Future Mobility Day #4



What Fleets Want



Zero Upfront Costs



**Low carbon fuel at
comparable costs to diesel**



**Simple operations -
Minimal training**



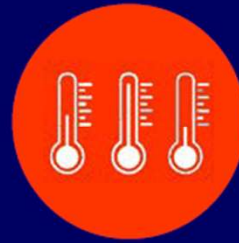
**No Range Anxiety
Fast fill up**



After-sales support



**Proof of Real-time
benefits**



Works in cold temperature



**No loss in Payload
High Power Output**

Hydra's Proprietary Conversion Kit

Simple 2-day conversion to run hybrid of hydrogen & diesel



H₂ tanks & gas handling components behind or under cab 40 kg (1,000 km)



H₂ injection manifold in-line with air intake blends H₂ and air before entering engine block
NO engine modification



Dedicated controller and wiring harness behind the dashboard (ECU)
NO interception/modification of OEM ECU messages

Hydra's IP



PROPRIETARY ECU

*Hardware & software built from the ground up in house
Designed & spec'd by Hydra for specific outcomes*

UNIQUELY PLATFORM AGNOSTIC

*Can work in any internal combustion application
Easy and fast to implement to grow & scale at speed
through auto-calibration made possible by machine
learning (others would use manual calibration taking
months to adapt to a new make and model of vehicle)*

FIRST TO INTEGRATE MACHINE LEARNING

*Hydra has more data than potential new market
entrants from having trucks on the road since 2016
A larger data pool enables Hydra to integrate machine
learning to optimise power output and fuel efficiency
alongside increased diesel displacement*

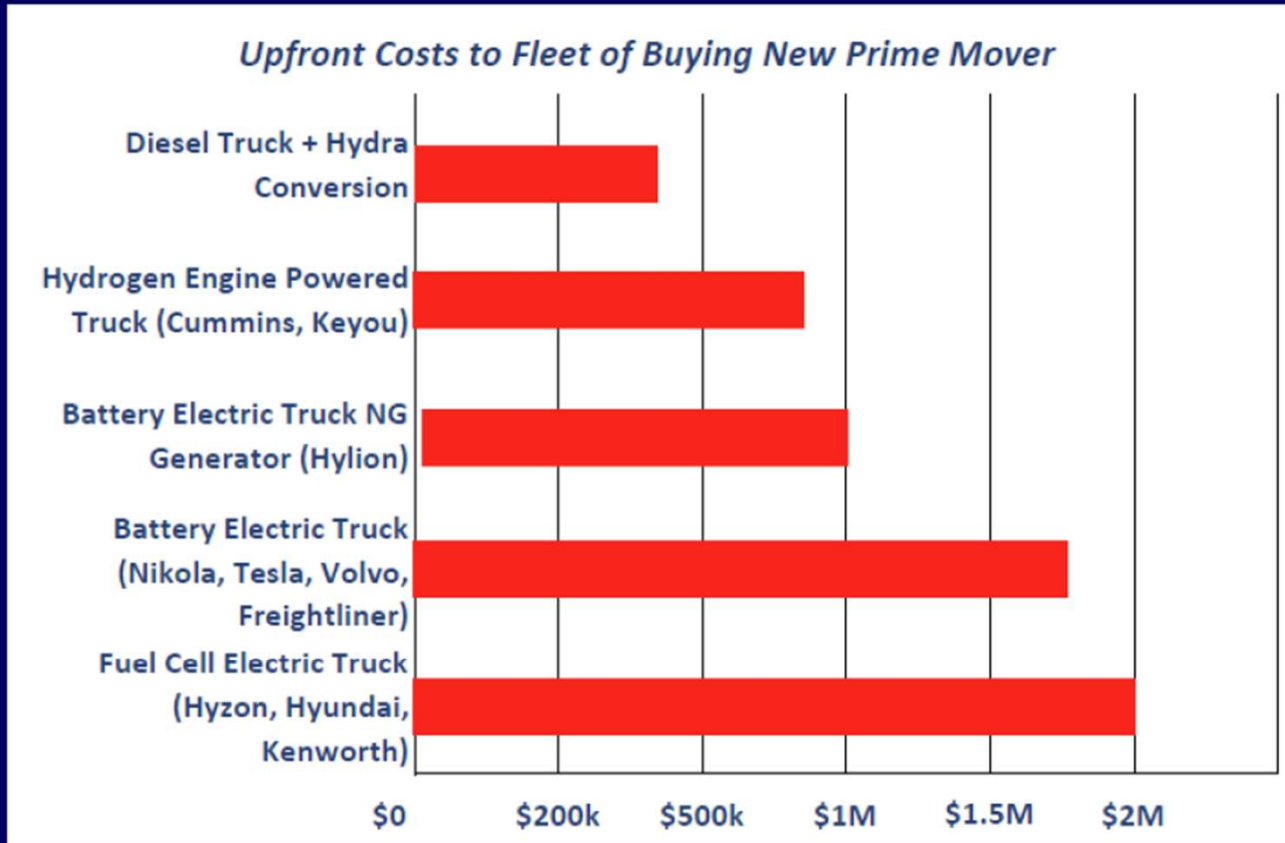


First company in the world to put hydrogen co-combustion heavy duty trucks on the road

300,000 kms driven and counting

- ✓ On-road data since 2016
- ✓ 1000 km range on average
- ✓ Same/superior performance compared to diesel
- ✓ Refueling in approx. 6 min
- ✓ Demonstrated all weather performance down to -46 C
- ✓ Emissions reductions up to 40%
- ✓ System ***DOES NOT*** modify the engine
- ✓ Safety operation- Zero incidents
- ✓ Happy drivers

How Hydra Compares to Other Alternatives



- Cost: No upfront cost in HaaS model; No increase in operating costs with H2 at diesel parity
- Performance: Proven to get equivalent or better power/torque than diesel-only
- Range of 1000 km - switches to diesel-only mode if H2 runs out
- Mass: Hydra's kit is 740kg
- Hydra only company with years of data needed for auto-calibration

Vehicle Safety Systems



Behind-the-cab mounted storage tanks; pressure, temperature, fire, impact, and rifle tested



T-PRD's on both ends of each tank; will safely vent hydrogen if over-temperature (110°C)



PRD located on low pressure line; will safely vent H2 if over-pressure (10 Bar)



Continuous leak-check; System will close all valves if a leak occurs and will notify operator



On-board diagnostics; Faults on the vehicle or on the system will disable the system and close all valves

Weight and Power

NO LOSS OF PAYLOAD

Hydra's conversion kit adds just over 700kg to the weight of the truck, mainly due to the hydrogen tanks mounted behind the cab. However, the Provinces of BC and Alberta enacted a blanket weight allowance of 1000kg for heavy-duty trucks fuelled by hydrogen.

Other provinces are considering similar policy changes to encourage adoption of clean fuels.

NO LOSS OF POWER

Hydra's trucks do not experience a loss of power when climbing hills even on the steepest of routes. Drivers have noticed a boost of power even on steep climbs.



HYDROGEN FUELLING

To refuel there needs to be hydrogen connected to a refuelling station, which is done through storage tanks. Hydrogen refuelling at 350 bar can also be an add-on to an existing cardlock or standalone integrated station that offers both hydrogen with diesel.*

*The diesel is not supplied by Hydra.

Refuelling takes under

10 minutes

and can be done at
the same time as diesel

Demonstration Unit - Status



PRIME MOVER

Wasco has selected a 2021 Freightliner Coronado 114 6x4 prime mover

FUEL SYSTEM

350bar featuring 5 x horizontally configured, rack mounted, behind the cab Type III cylinders

DESIGN, SUPPLY, INSTALLATION

Design complete, cylinders, valving and electronics ordered, truck ready

CERTIFICATION

Early consultation with Qld Gas Inspectorate during design and materials selection to ensure certification is achieved



For demonstration during Q3

For more information

EMAIL



sales.aus@wascoenergy.com.au



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[LinkedIn.com/company/hydra-energy](https://www.linkedin.com/company/hydra-energy)



[@HydraEnergyNow](https://twitter.com/HydraEnergyNow)



[youtube.com/c/HydraEnergyCanada](https://www.youtube.com/c/HydraEnergyCanada)



Hyzon ANZ | Remondis Australia

Waste Collection Side - Loader



Zero Emission Waste Collection.

REMONDIS Wollongong . Waste Collection Side-Loader

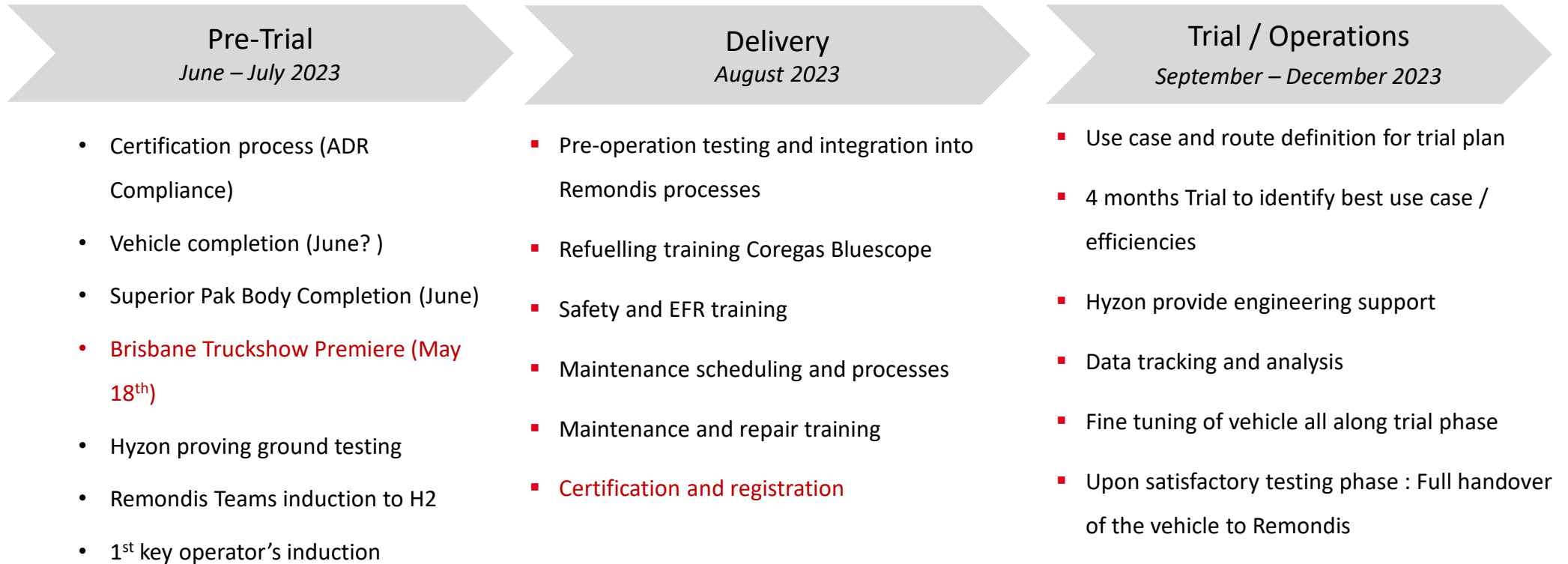
- Remondis will commence operations of a Hyzon/Superior Pak hydrogen fuel cell powered collection vehicle this year.
- Q3 / Q4.
- Hydrogen fuel cell heavy vehicles are a replacement of diesel heavy vehicles.
- They will:
 - reduce carbon emissions
 - improve particulate emissions
 - reduce noise.
- At a cost



HYZON FCEV CHASSIS VS DIESEL EQUIVALENT

	Hyzon FCEV	Diesel Equivalent
• Fuel Cell	110 kW Net (150 Gross)	-
• Engine power	275 kW (410 kW peak)	260 kW
• Torque	2,400 Nm peak	1,600 Nm peak
• Gearbox	4-Speed	6-Speed
• Max Speed	100 km/h	100 km/h
• Batteries	55 kWh	-
• Tare Mass	+10 %	-
• Tanks	25 kg (H2) @350 bar	200l (diesel) / 25l
• GVM	AdBlue	
• Use case : 1,500 lifted bins on 8-12 hours duty cycle – one tank of H2	22.5 T	22.5 T

HYZON FCEV GARBAGE COMPACTOR STEPS TO OPERATIONS



HYZON FCEV TRIAL EXPECTED OUTCOMES

- Real life testing of promising Fuel Cell technology for garbage application
 - Performances testing
 - Refine products on key learnings
- **New technology adoption**
 - Change management from ICE to EV or FCEV
 - On-site requirement for operations
 - Operators' adoption curve
 - Hydrogen refueling
- Decarbonisation : CO2 reduction evaluation
- Running costs
 - Vs ICE
 - Vs EV



Hyzon ANZ | Remondis Australia

Waste Collection Side - Loader

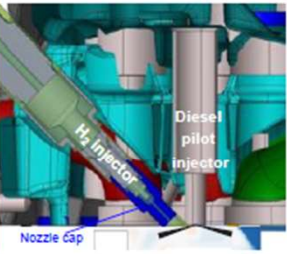


Expectations

- Zero emission collections in Wollongong and Shellharbour City Councils
- Safe operation
- 1500 lifts/day. 3,000,000 lifts over vehicle life
- A Reduction of 24,000l of Diesel / year / vehicle.
- Remondis goal is parity with current heavy vehicle operational capability and operational cost
- Others will follow

Hydrogen-diesel hybrid engine

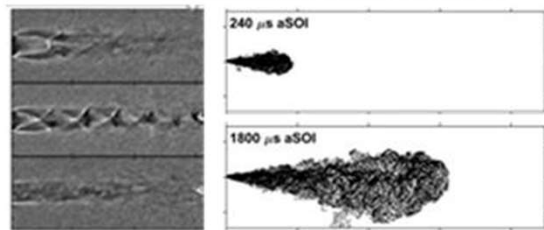
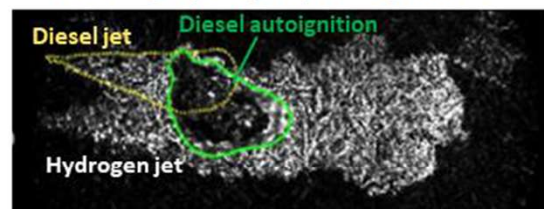
Professor Shawn Kook
The University of New South Wales



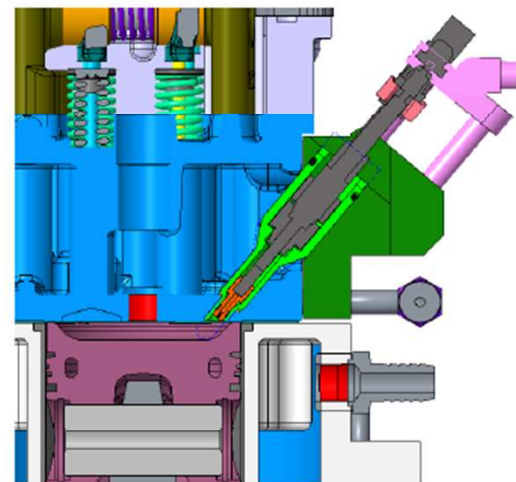
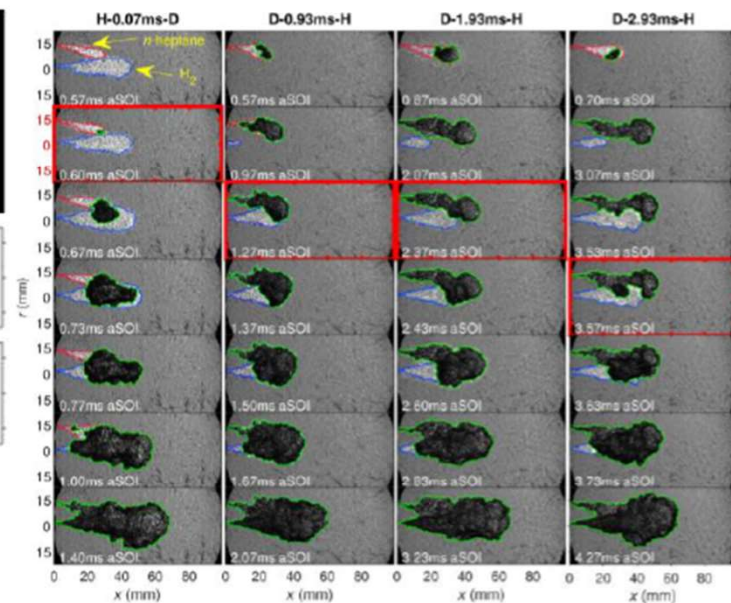
UNSW hydrogen engine research (2018-2021) and patents (2022)

- Scientific research using optical diagnostics has found innovative methods for hydrogen jet formation and diesel pilot flame ignition.
- This has been demonstrated in a single-cylinder research engine where a high-pressure hydrogen direct injection is achieved using an inhouse-developed technology.
- Australian patent application and PCT conversion application were successfully made.

Reacting hydrogen jet diagnostics



Rorimpandey P., Yip H.L., Zhai G., Yip P., Srna A., Wehrfritz A., Kook S., Hawkes E.R., Chan Q.N., "Hydrogen-diesel dual-fuel direct-injection (H2DDI) combustion under compression-ignition engine conditions," International Journal of Hydrogen Energy 48(2):766-783, 2023



Hydrogen-diesel direct injection dual-fuel system for internal combustion engines, Australian Patent Provisional Application No. 2022900118, filed 21 Jan 2022, International Application No. PCT/AU2023/050019, filed 16 Jan 2023.

Competitive advantages of the hydrogen-diesel hybrid engine

Hydrogen Fuel Cell

High efficiency	Poor durability
Zero tailpipe CO ₂	High costs
	Precious metal content
	Must dispose current tech



Gaussin H₂ vehicle

Hydrogen Spark Ignition ICE

100% H ₂ operation for zero CO ₂	Low efficiency
High durability	No backup mode
	Must dispose current tech



Cummins H₂ SI engine

Hydrogen Port-injection Diesel ICE

Low costs	H ₂ ratio limit means circa 10% CO ₂ reduction
Diesel backup	Backfire, knocking and NOx
High durability	
Retain existing tech	



CMB Tech retrofit

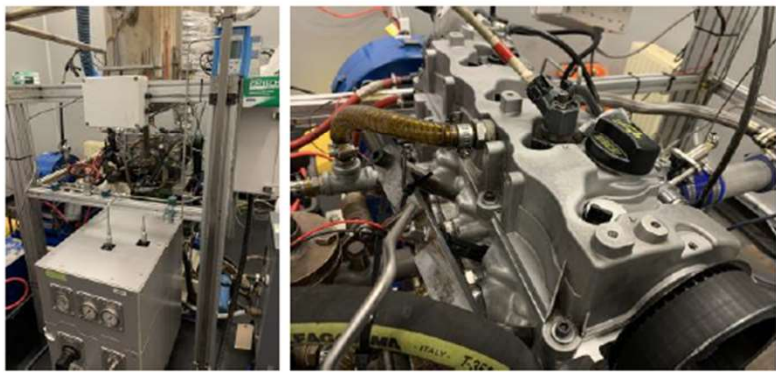
Hydrogen Direct-injection Diesel ICE

70+% CO ₂ reduction	Higher cost than port injection diesel ICE
Diesel backup	
High durability	
NOx control	No zero CO ₂
Retain existing tech	
High efficiency	



Proven in a small engine and ready for scale up (0.5L/cyl → 1.0L/cyl → 2.7 L/cyl)
 Complete Current Planning

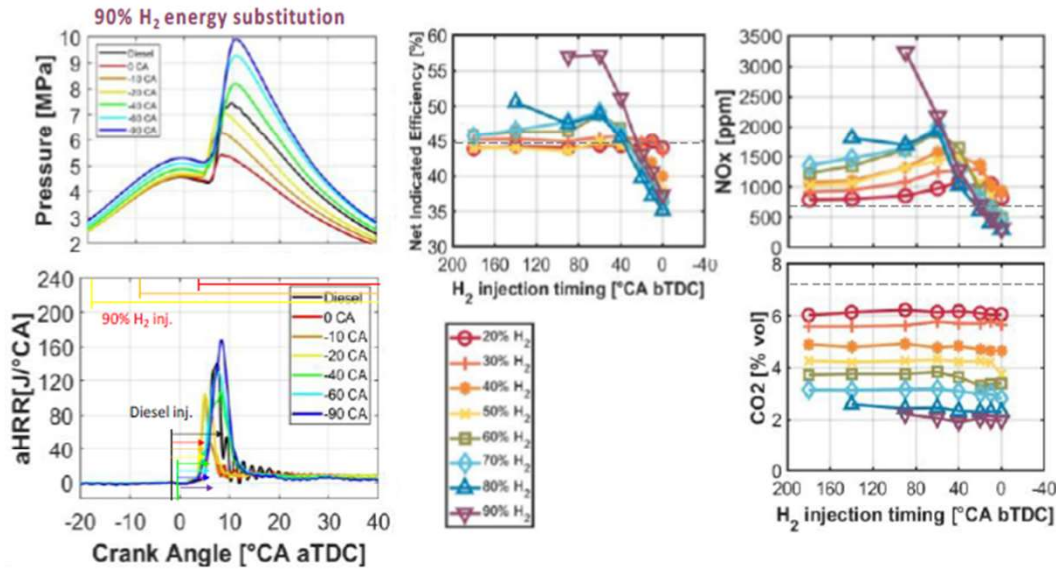
UNSW Hydrogen Engine Facility



0.5-litre/cylinder single-cylinder engine



1-litre/cylinder single-cylinder engine



Liu X., Seberry G., Kook S., Hawkes E.R., Chan Q.N., "Direct injection of hydrogen main fuel and diesel pilot fuel in a retrofitted single-cylinder compression ignition engine," International Journal of Hydrogen Energy 47(84):35864-35876, 2022

- Up to 57% indicated engine efficiency: 26.7% efficiency improvement compared to a diesel baseline
- Full control of combustion modes – premixed or mixing-controlled hydrogen combustion
- At fixed efficiency/power and NO_x emissions, **71.4% CO₂ reduction**

Commercial readiness

Small diesel engines



Ready for product development and demo

- Small engines with **0.5 litre/cylinder** are ready for real site demonstration and commercial product/service development.
- An initiative for airport tractor applications.

Medium-duty diesel engines



Scale-up development in progress

- Medium-duty engines with **1.0~1.5 litre/cylinder** are currently under development
- Targeting Q1 2025 for the first on-process deliveries.

Heavy-duty diesel engines



Scale-up research

- Heavy-duty engines with **2.0~3.0 litre/cylinder** will be developed.
- A 3.5-year research project funded via the Trailblazer program will be commenced in Q3 2023.

Business opportunity?



Towards **DECAR**boised **I**nternal **C**ombustion **E**ngines

- DECARICE will be founded as a UNSW spinout.
- DECARICE will lead commercialisation of the new hydrogen-diesel engine technology.

CO-FOUNDERS



Goran BOZIC
CEO

Regional Manager APAC for Cox Marine
UNSW alumnus, University medallist
12 years in UK engine industry
including successful startup



Dr Shawn KOOK
CTO

Professor, Director UNSW Engine Lab.
240+ published papers, 5500+ citations,
\$13+m research funding including
large-scale industry projects

Technology implementation stream



First time only for unfamiliar engine designs

Secondary and optional business streams



Training



Support



Warranty

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Questions?



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Thank our speakers

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