Hydrogen retrofit solutions for commercial vehicle applications

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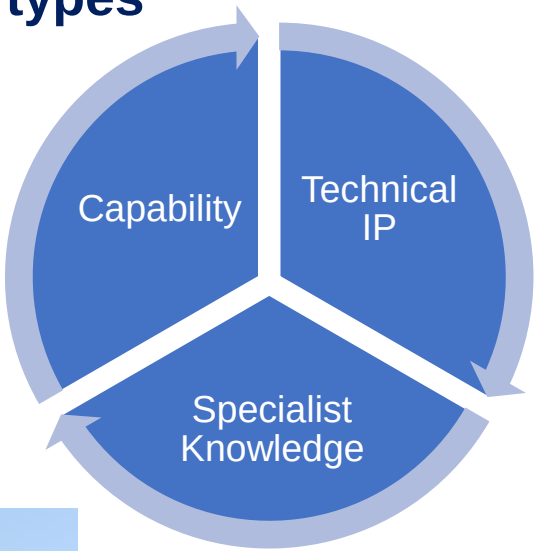
Our core capabilities allows us to provide solutions for multiple vehicle types

- Vehicle requirement knowledge
- Vehicle standards and regulatory compliance
- Economic model of replacement cost and total lifetime costs
- H2 supply chain knowledge
- Patented engine technology
- Track record of delivering different solutions across a range of vehicle types



ULEMCo offers practical solutions that deliver ultra-low emission trucks, NOW, and a route to zero in less than 5 years

H2ICED Hydrogen Dual Fuel	FCRX Fuel Cell Range Extension	HYICE Zero Emission H2 Combustion
Available now	Available now	R&D for small volume launch 2024
Existing or new vehicles (including LGV,HGV, Specialist, Off-Road, & Construction Equipment)	Existing or new electric vans or small buses	New or nearly new specialist 7.5t urban trucks with replacement engines
Up to 40% carbon emission reduction	Zero emission	Zero emission
Typical daily H2 use per vehicle between 5-15kg*	Typical H2 use per vehicle of up to 15kg per day	Typical H2 use 30-40kg a day
Improved real-world air quality emissions	Roof mounted power module available	Uses conventional chassis and vehicle systems

*Depending on duty cycle

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Current R&D Projects

A hybrid drivetrain, utilising a hydrogen combustion engine and a battery system, offering a zero-emission solution with the use of current available technologies.

A first for the UK market, a zero emission, hydrogen fuel cell ambulance. The vehicle is a fully functional ambulance, with an integrated fuel cell acting as a range extender on top of an electric vehicle chassis.

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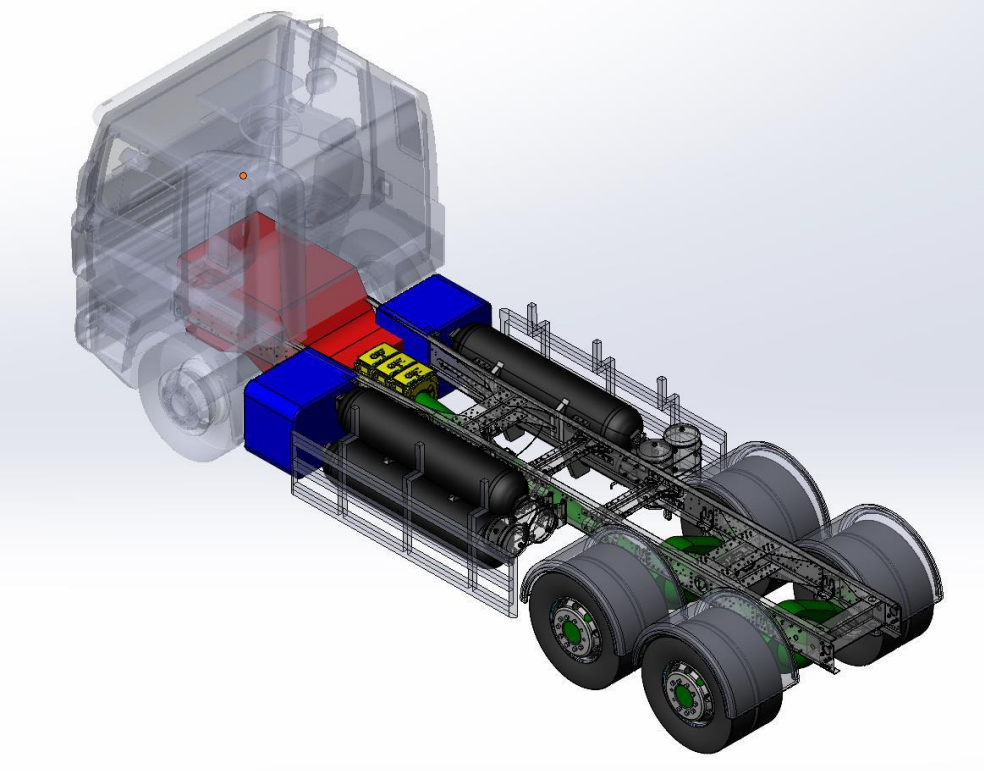
HDV Feasibility Study

- Looking specifically at hydrogen zero emission options for a DAF CF
- Recorded data allowed the analysis and calculation of both energy demands and power needs
- An “upcycling” approach was preferred due to the reduction in cost and waste
- Packaging constraints ruled out fuel cell options
- Hydrogen combustion engines are still in their infancy and unfortunately are underpowered for a vehicle of this size
- Hybrid drivetrains will provide the most likely option, but currently only for smaller trucks

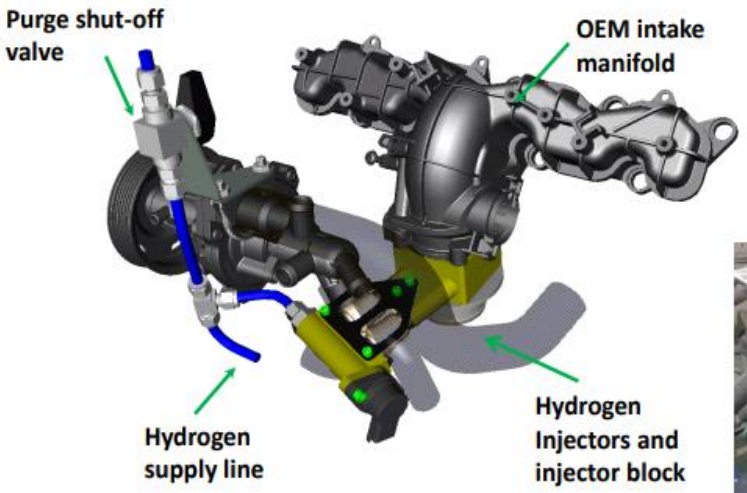
Concept Design



- Hybrid drivetrain allows for the removal of the SCR, AdBlue tanks, etc. making more room for hydrogen components
- Proposed design would incorporate SRMs and a battery system, making the vehicle more efficient
- Overall vehicle packaging would not change

ULEMCo's Hydrogen Dual Fuel conversion service

- Average displacement for of HGV in urban cycle 20-40% giving direct CO2 tailpipe emission savings
- Addition of on-board hydrogen storage
  - ✓ 350 Bar EC79 approved
- Air inlet modified to allow for the addition of hydrogen gas injectors
- Hydrogen system engine control (ECU) and safety systems
- Customer bespoke post conversion calibration
- Specific calibration to optimise hydrogen use in relation to duties, location, driver behavior etc.
- Driver & Maintenance team training
- Duty cycle optimisation
- Supplied with individual vehicle approval
- Warranty and maintenance support



H2ICED® Hydrogen Dual Fuel

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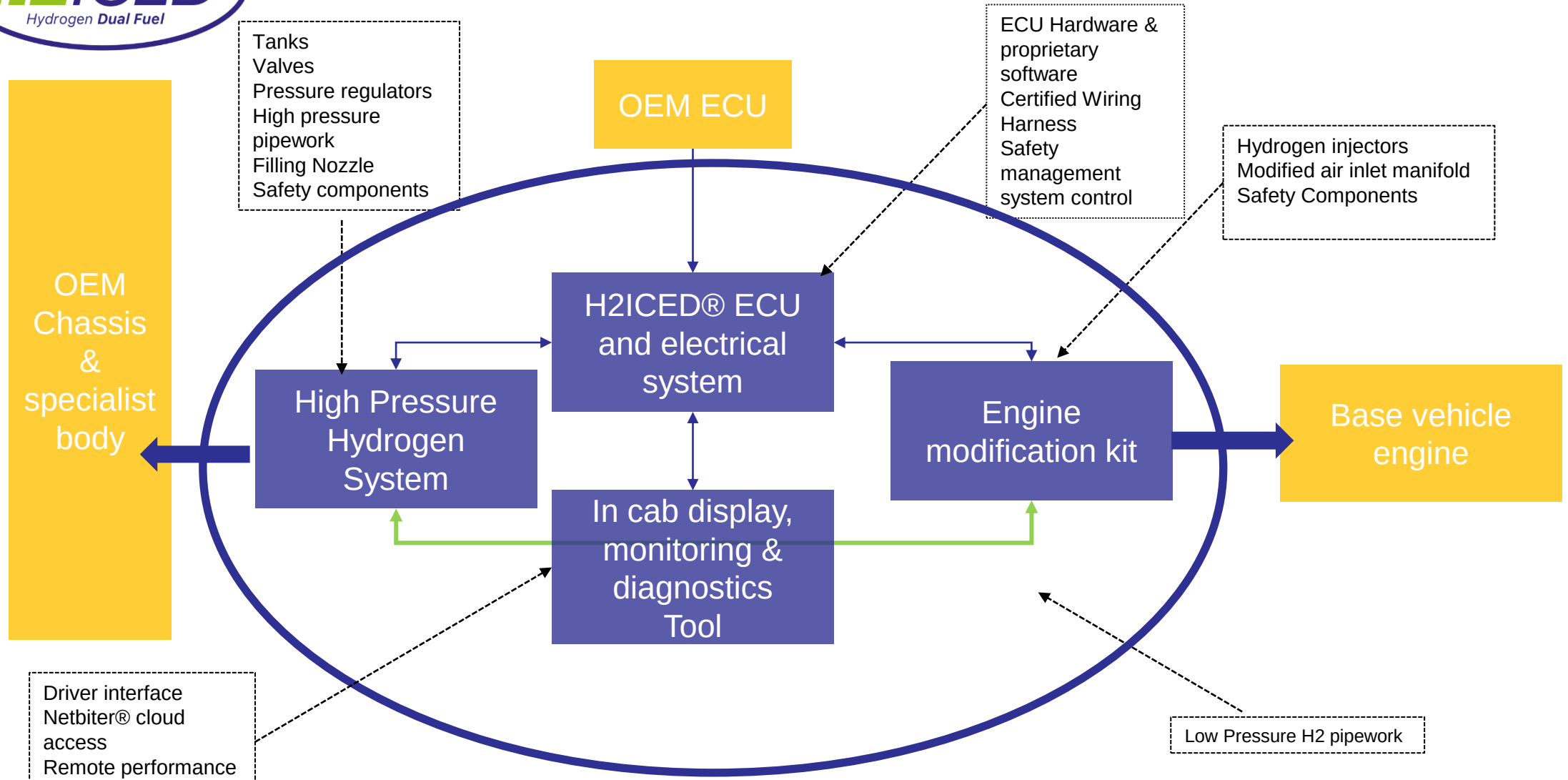
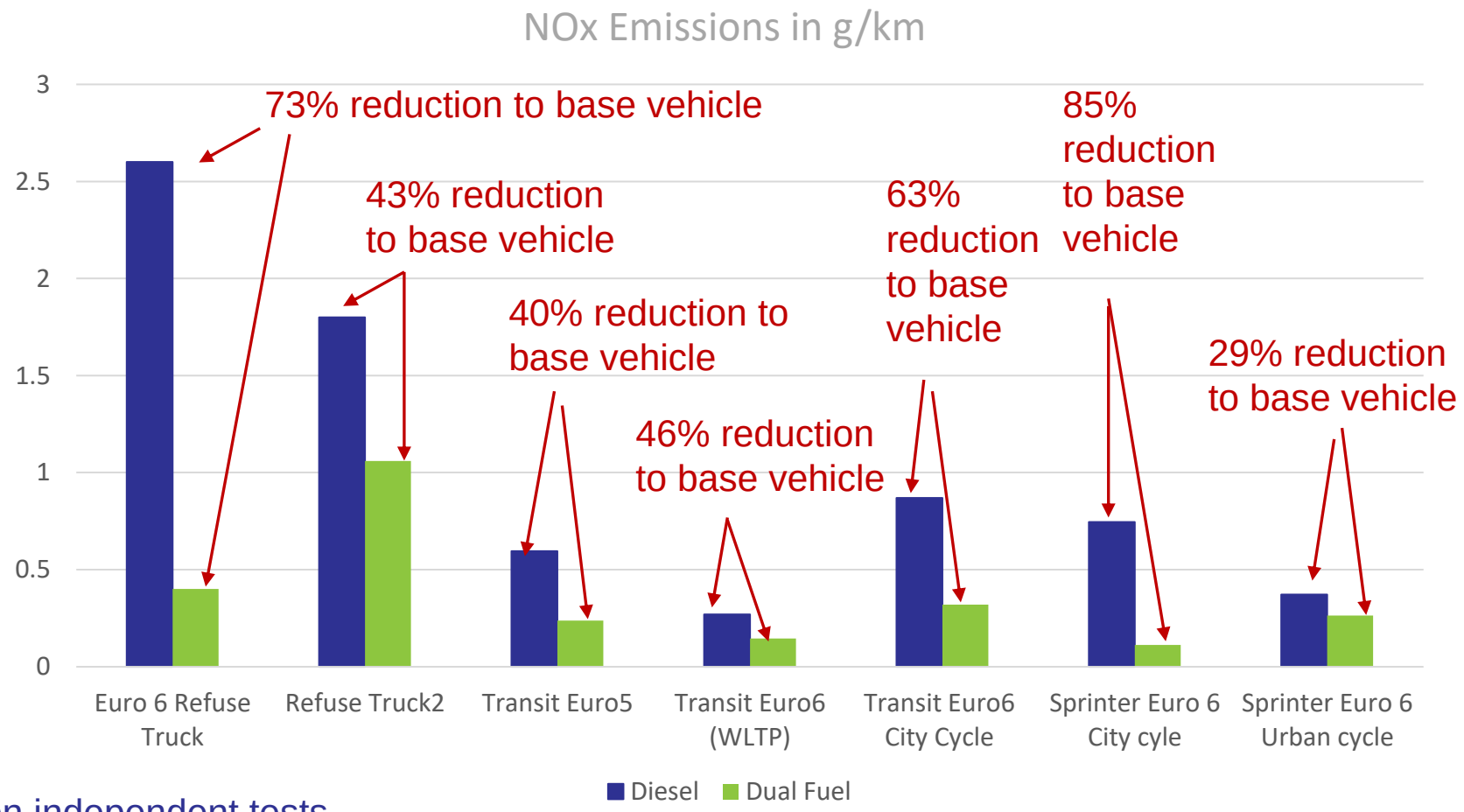
Components of a conversion



At the same time as delivering beyond Euro 6 emission air quality standards



*based on independent tests

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UK Government Support “Low Emission Freight Trial”

Conclusions: Vehicles saved over 15 Tonnes CO2 during the course of project

Vehicle	KM driven in hydrogen dual fuel	Hydrogen used (kg)
Merc Econic 1 Aberdeen	11,611	485
Road Sweeper	16,506	483
Merc Econic 2 Aberdeen	5,308	258
Denis Eagle 1 Westminster	2,663	119
Denis Eagle 2 Westminster	2,343	99
Transit Van 1	8,338	42
Peugeot Boxer Patient Transport	5,769	79
Transit Van 2	2,446	18
Merc Sprinter Refrigerated	2,279	17
Merc Sprinter LFB1	862	12
Merc Sprinter LFB2	435	5

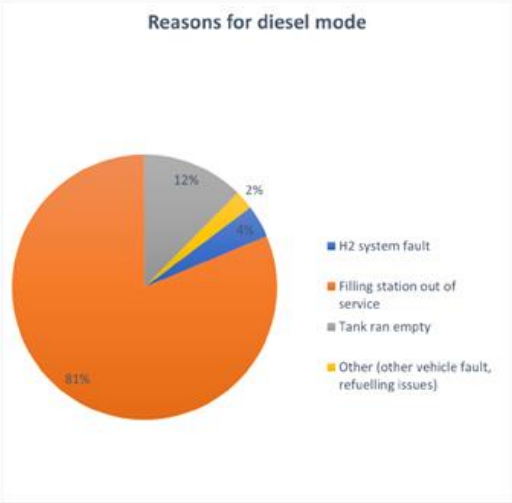

Figure 11 Reasons for the vehicles running in diesel mode

Emissions testing – GHG emissions

LowCVP Low Carbon Vehicle Partnership

Tech 6 - DFH VANs

	LEFT Tailpipe g/km	Diesel Tailpipe g/km	LEFT WTW (LowCVP H_2 factor)	Diesel WTW (Defra factors)	WTW % change
Long Haul (1)	210	334	465	412	+13%
Regional	152-202	280-301	405-458	346-371	+17-24%
Urban	122-203	237-291	351-419	293-359	+17-20%
City Centre	126-249	298-358	509-548	368-442	+24-38%

Tech 7 - DFH HGV

Long Haul	153	243	350	300	+17%
Regional	160	261	373	322	+16%
Urban	207	285	394	351	+12%
City Centre	250	372	534	459	+16%

Tech 8 – DFH RCVs

Euro VI	2110	2550	3360	3140	+7%
Euro V	2400	2770	3900	3420	+14%

- Using a factor derived for the most common hydrogen production pathway (not just for transport), GHG emissions would rise by typically 10-30%
- If hydrogen derived from electrolysis with renewable electricity is assumed (as is more commonly the case for hydrogen in transport), GHG savings of 10-35% would be achieved

10-35% GHG savings with green hydrogen

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Monitoring and Reporting

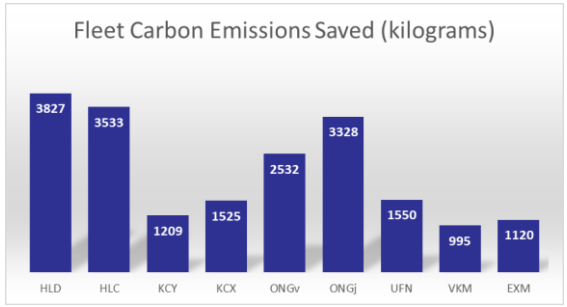
Financial Year 2022-23

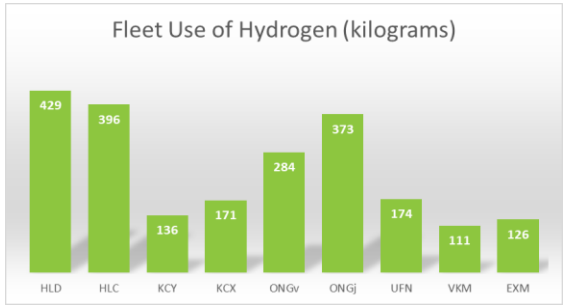
Carbon Emissions Saved (KGs):

19618

Hydrogen Used (KGs)

2199





- Argos Netbiter
- Remote diagnostic tool
- Live daily monitoring
- Monthly and yearly reports for customers
- Massive CO2 Savings!
- Displacing 20-52%

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Real-world data - Sweeper with an auxiliary engine

- The sweeper uses hydrogen in both the vehicle powertrain engine and the on-board auxiliary engine, the latter seeing displacement rates of over 50% of the energy coming from hydrogen.

- This application and others like it such as RCV, Gritters etc are ideally suited for use of hydrogen from back-to-base refuelling infrastructure, providing base load for competitive hydrogen supplies, cracking the “chicken and the egg” conundrum, as the vehicle can still operate as a full diesel vehicle in lieu of hydrogen supply.

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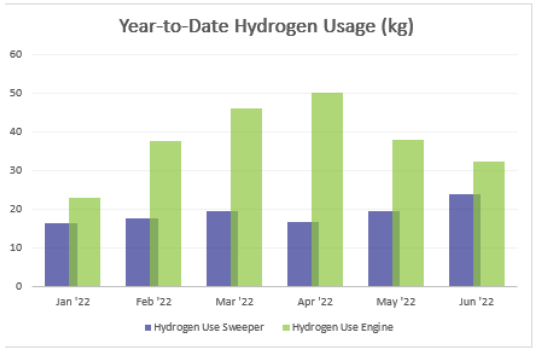
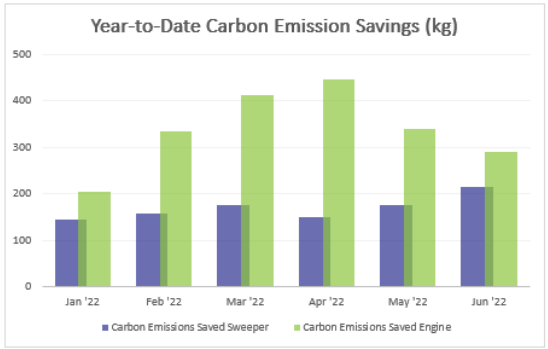
Yearly Overview - Jan '22 to June '22

Combined Key Findings	
Total H2 Used (kg)	341
Diesel Equivalent L H2	1120
Total Miles in Diesel Mode	744
Total Miles in H2 Mode	1846
Total Miles	2590
Total CO2 Saved (kg)	3045





YTD Summary

Sweeper

Key Indicators	
Diesel Equivalent L H2	374.74
Displacement Rate %	30%
Litres/100km	51.26
Miles Per Gallon (MPG)	5.51
KM per KH h2	26.00
CO2 Savings (kg)	1019
Monthly Measurables	
KMs	4168
KMS DF	2971
% H2 Mode	71%
Regen Events	8
H2 Ran Out	2
MIL Lamp	0
H2 Fault	58
Diesel L	1761.83
H2 Mode Diesel L	885.05
KG H2 Used	114.25
H2 Refuelled	50.00
Energy	
Equiv. Fuel Energy Diesel	18055.23
Equiv. Fuel Energy H2	3838.80
Energy Consumption (kwh)	21894.03
H2 Energy Use (kj/km)	4653.06
H2 Mode Diesel Energy	n/a
Miles	
Diesel Miles	743.78
H2 Miles	1846.09
Total Miles	2589.87

JCB Engine

Key Indicators	
Diesel Equivalent L H2	744.87
Displacement Rate %	51%
Litres/100km	
Miles Per Gallon (MPG)	
KM per KG H2	
CO2 Savings (kg)	2026
Monthly Measurables	
Hours	0
Hours DF	208
% H2 Mode	#DIV/0!
Regen Events	0
H2 Ran Out	43
MIL Lamp	0
H2 Fault	11
Diesel L	1117.50
H2 Mode Diesel L	714.65
KG H2 Used	227.09
H2 Refuelled	72.00
Energy	
Equiv. Fuel Energy Diesel	11452.14
Equiv. Fuel Energy H2	7630.36
Energy Consumption (kwh)	19082.50
H2 Energy Use (kj/km)	132107.57
H2 Mode Diesel Energy	n/a

- ✓ **CO2 emission savings**
- ✓ **Hydrogen usage**
- ✓ **Diesel savings**

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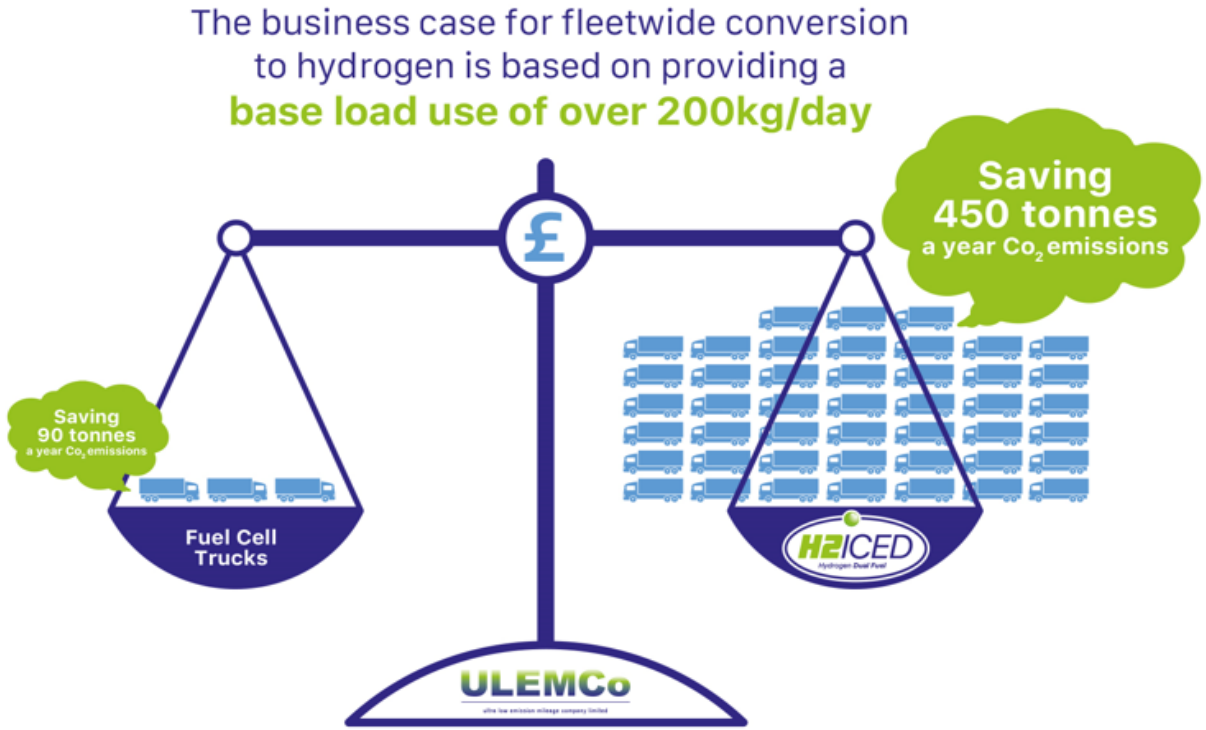
Hydrogen



The key to making a business case for hydrogen as far as fleet operators are concerned is to do it at scale, particularly when there are limited options for public refuelling.

Scale (say 20-30 back to base vehicles) enables you to spread the capital cost of the hydrogen refuelling infrastructure over a suitable volume of fuel to enable the costs to work out similar to diesel, at the same time as delivering a substantial carbon reduction.

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ULEMCo – making Hydrogen, tomorrow's fuel, TODAY

H2ICED®
Hydrogen Dual Fuel

- ✓ Arguably, the best value for money way to reduce carbon emissions
- ✓ Delivers results for urban driving without compromise for other circumstances
- ✓ Available now, using known technology
- ✓ No range anxiety

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