



Hydrogen Powertrains for Specialist Vehicles

How range extension enables “horses for courses”

alyne@ulemco.com June 2022

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



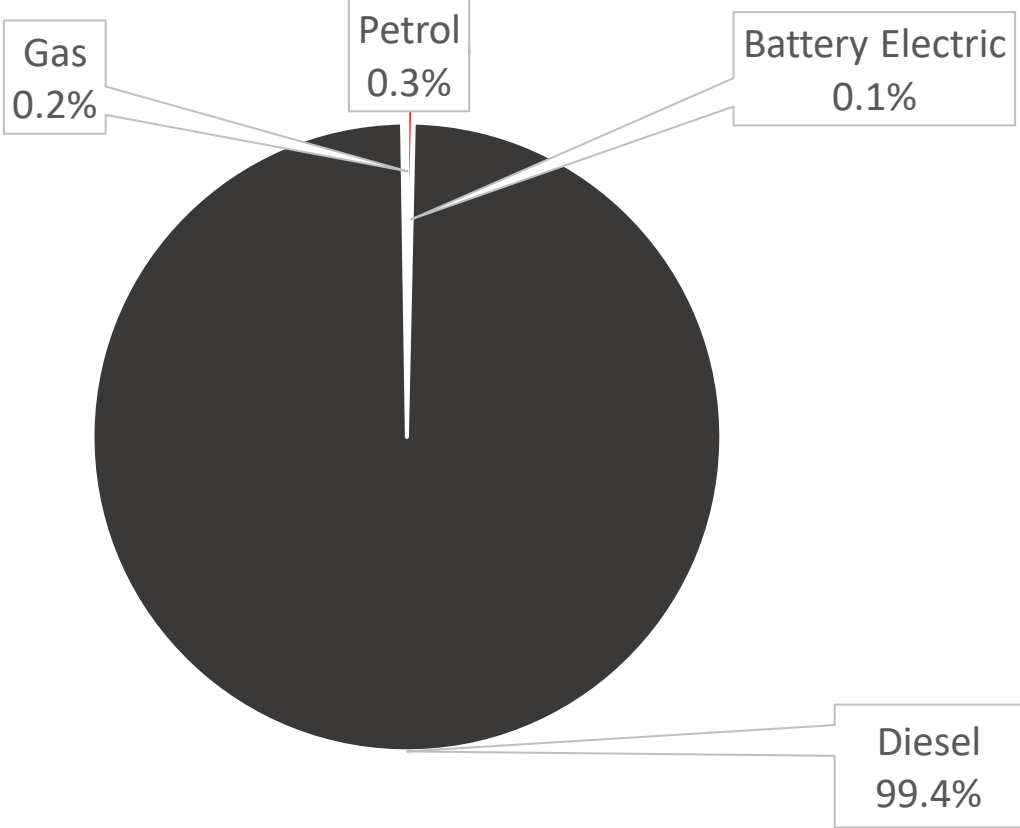
Concept	R&D	Prototype	Commercial	Long-Term Potential
Solutions already commercially available with clear road map to zero emissions ✓	HGV dual fuel conversion for Fife Council ✓	Low emission freight vehicle trials demonstrating fleet wide conversion ✓	Fleetwide conversion of 20 gritters for Glasgow City Council ✓	Strategically positioned conversion centres providing fleetwide conversions
LEFT project – roof top mounted fuel cell range extension ✓	Delivery of Nissan FC Rx™ to Aberdeen City Council ✓	Project Zerro – lead partner on first hydrogen zero emission ambulance ✓	NHS England zero emission ambulance procurement starts	Established Tier 1 supplier of fuel cell power train to specialist vehicle OEMs
Right sized engine concept formalised ✓	Collaborative work with CMB to prove 50kW generator engine at zero emissions ✓	Aircraft tow tug – first H2 engine in a mobile application	Series and parallel hybrid drivetrain conversion customer trials	Fleetwide retrofit capability



Why is hydrogen the right horse for the course?



Where 99.4% of heavy duty vehicles & machines are still powered by diesel



■ Petrol ■ Diesel ■ Gas ■ Battery Electric



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However to decarbonise “one size” WILL not “fit all”



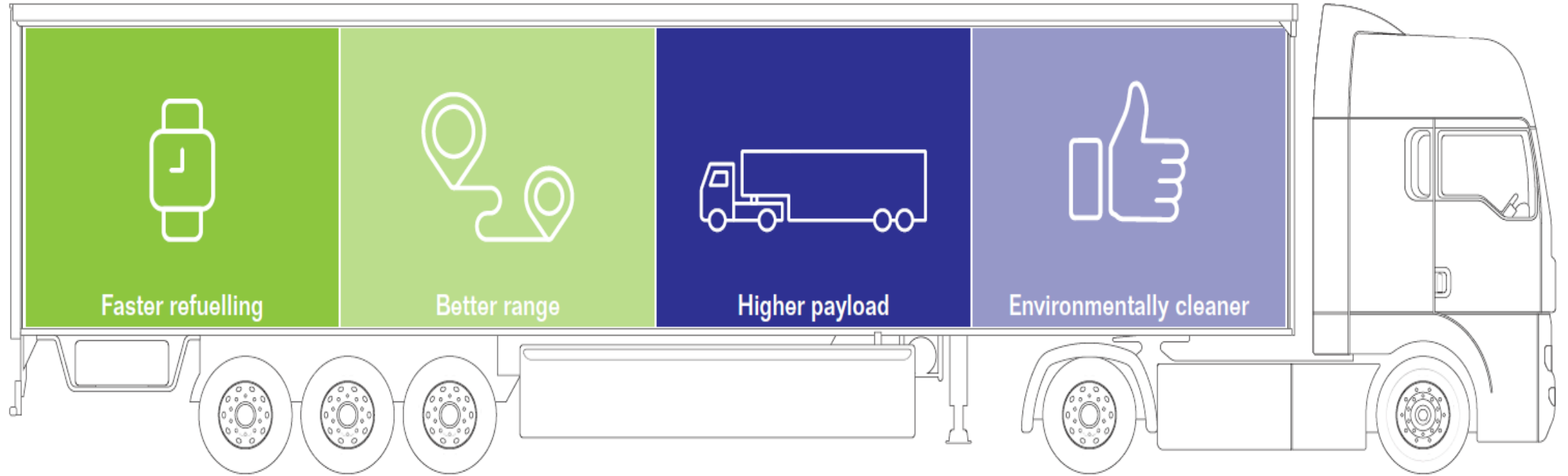
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What is needed to do the job?	Detail
Performance	<ul style="list-style-type: none"> High power Longevity of power Power take off
Flexibility of operation	<ul style="list-style-type: none"> Convenient Range Fast refuelling (productivity of the asset) Weight carrying Volume carrying
Capital cost efficient	Affordable within capital budget & replacement programmes
Operating cost competitive	<ul style="list-style-type: none"> Fuel efficient Fuel price competitive Accessibility to refuelling
Lifetime ownership cost effective	<ul style="list-style-type: none"> Certainty of operation over asset life Durability over life End of life asset value

Hydrogen has structural advantages versus battery alternatives in heavy duty and high utilisation use cases

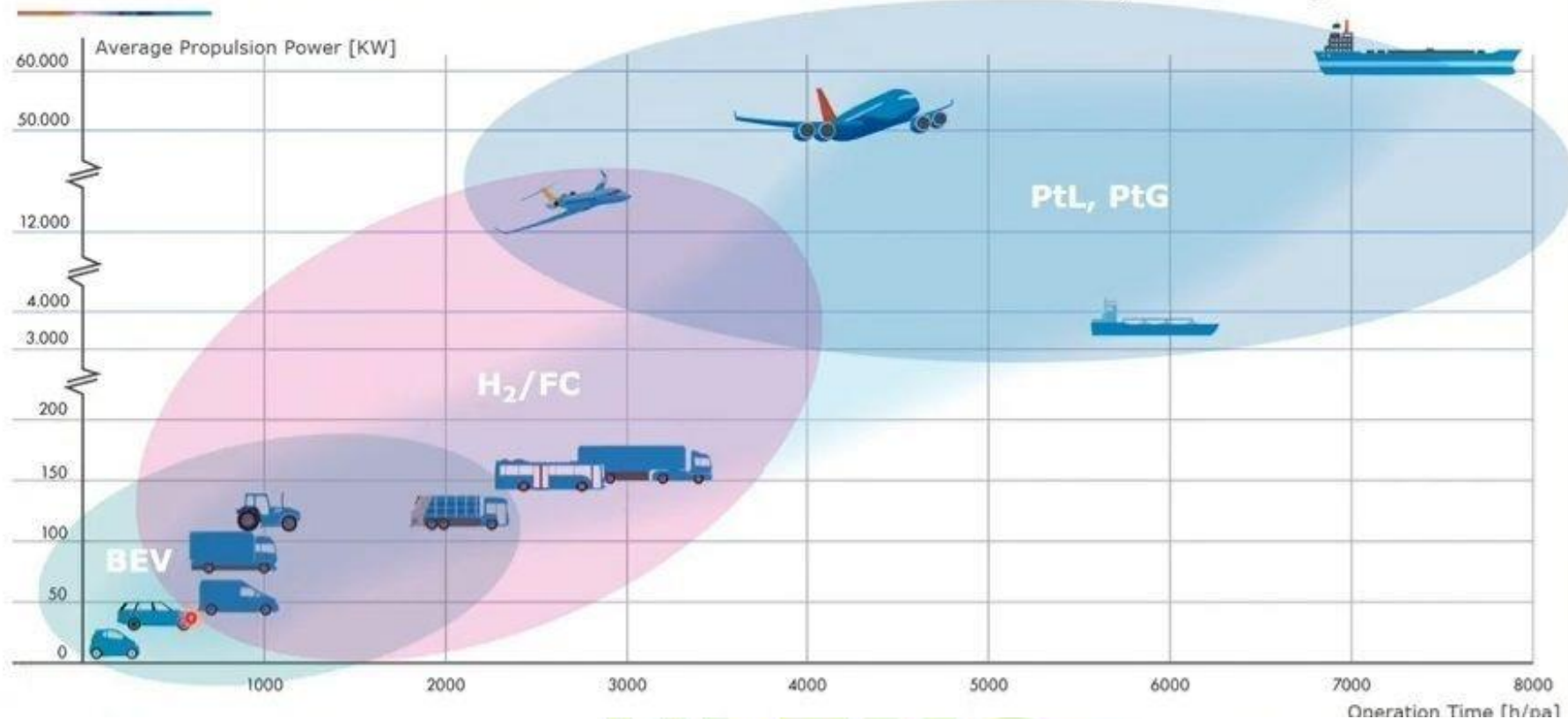
Advantages of hydrogen over battery electric vehicles



Hydrogen enables autonomy in high utilisation, 24/7 assets with significant advantages over battery technology

Zero-emission vehicles will be powered by a mix of hydrogen (fuel cell and H2 combustion) and batteries (using electricity)

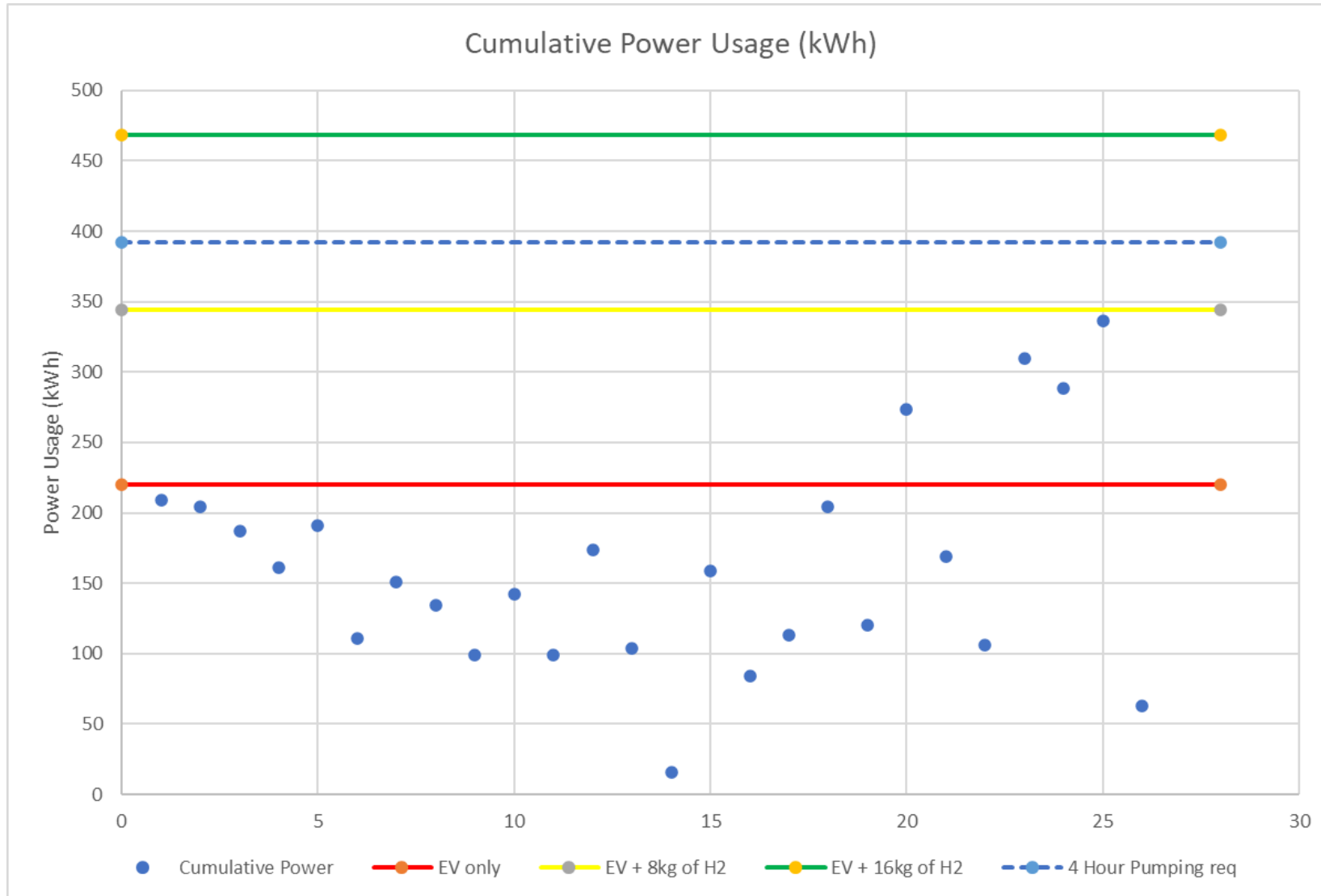
A Mix of Future Powertrains to meet the Sustainability Challenge



In the context of decarbonisation it's energy use that matters



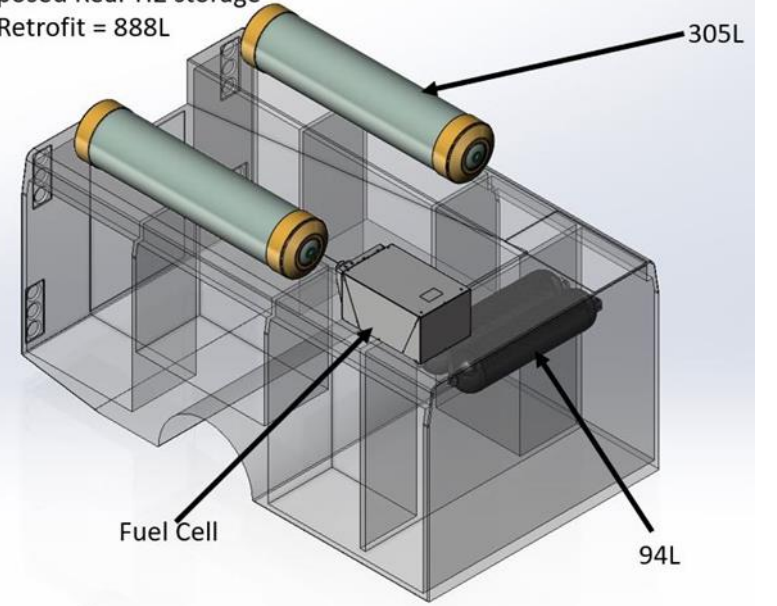
Daily energy use for a county based Fire Engine



Real world data gathered from HySPERT c/o Oxfordshire Fire Service

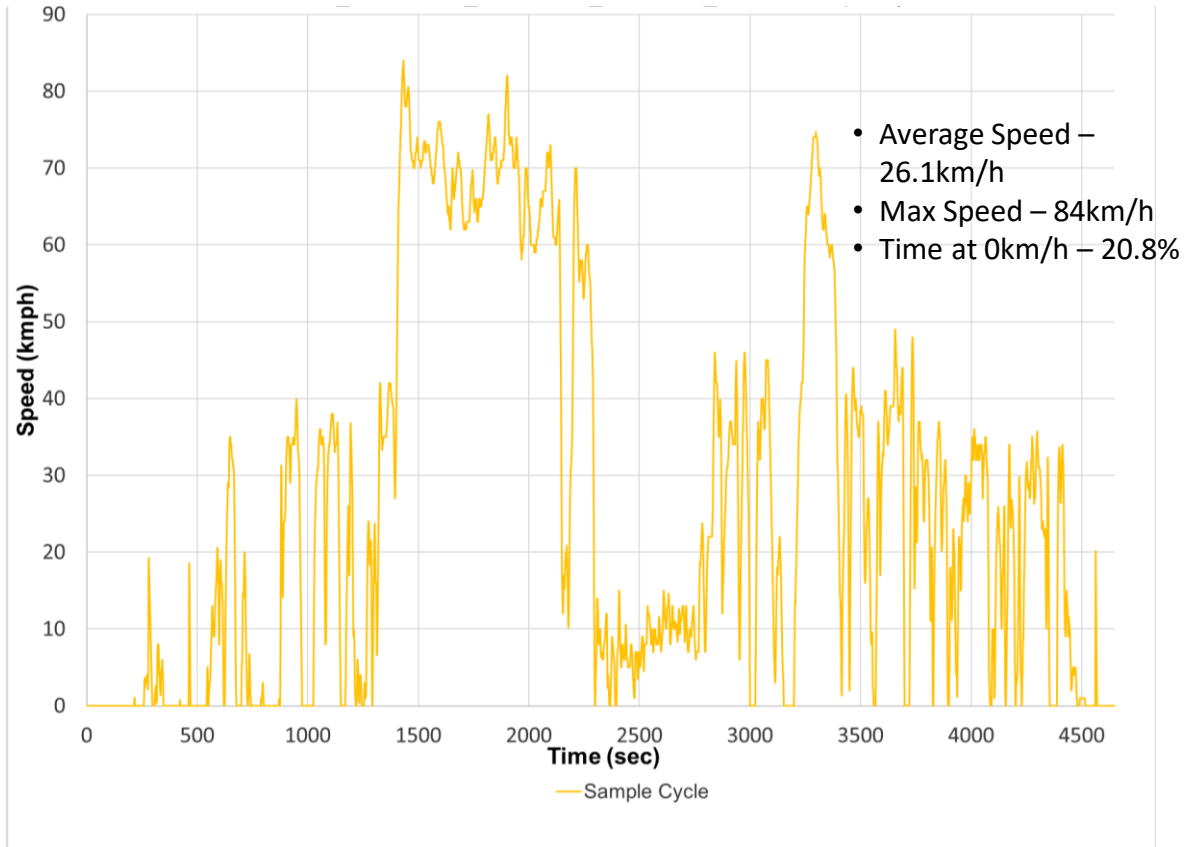
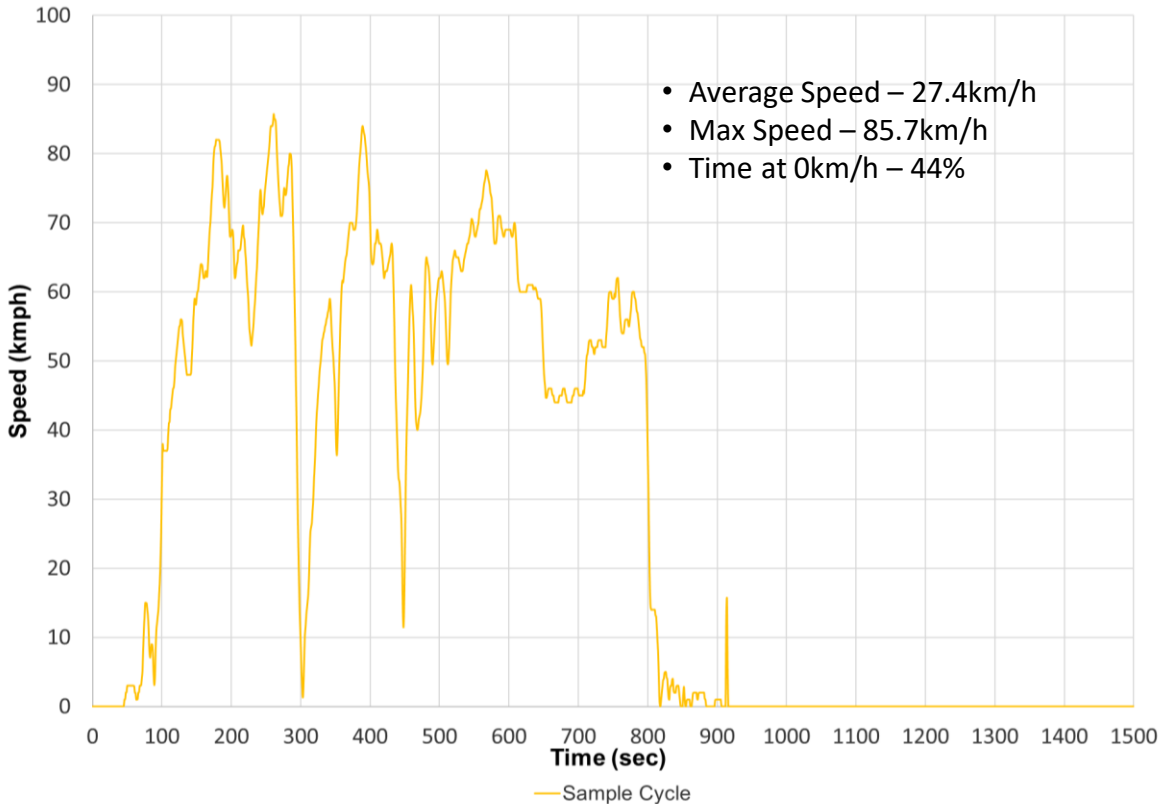


Proposed Rear H2 storage
for Retrofit = 888L





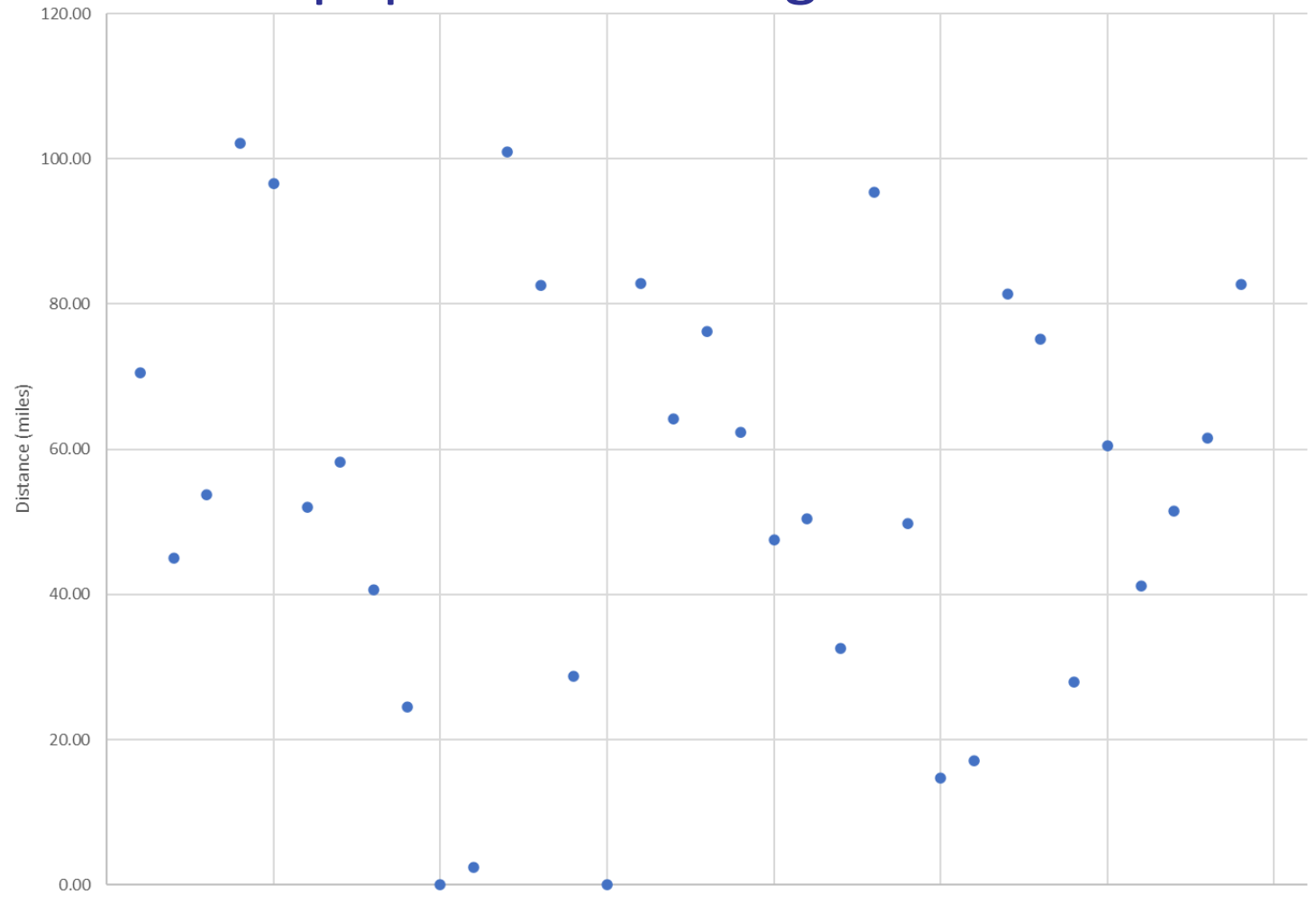
Real world Ambulance cycles are highly variable



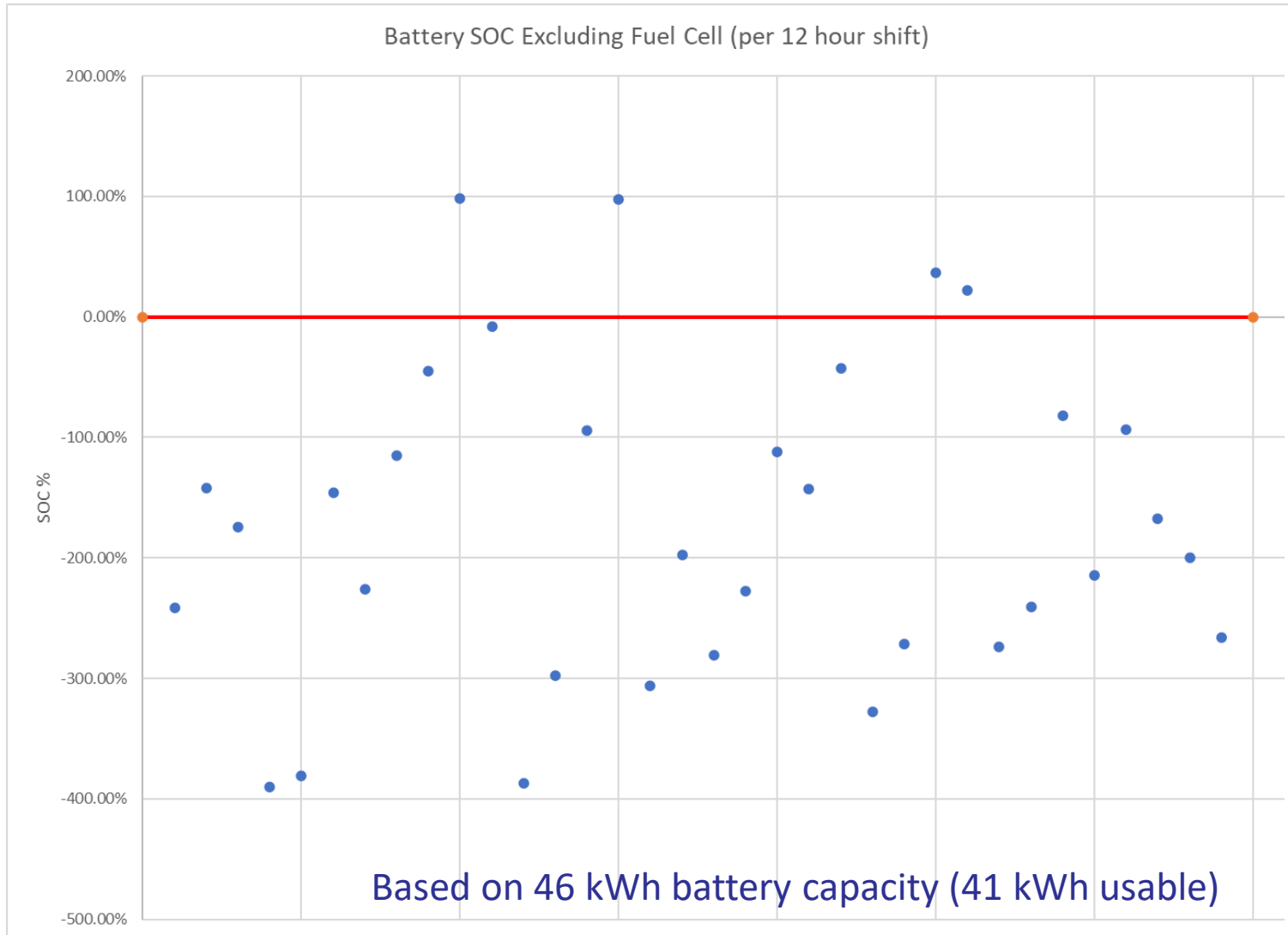
Real world data gathered from ZERRO c/o London Ambulance Service



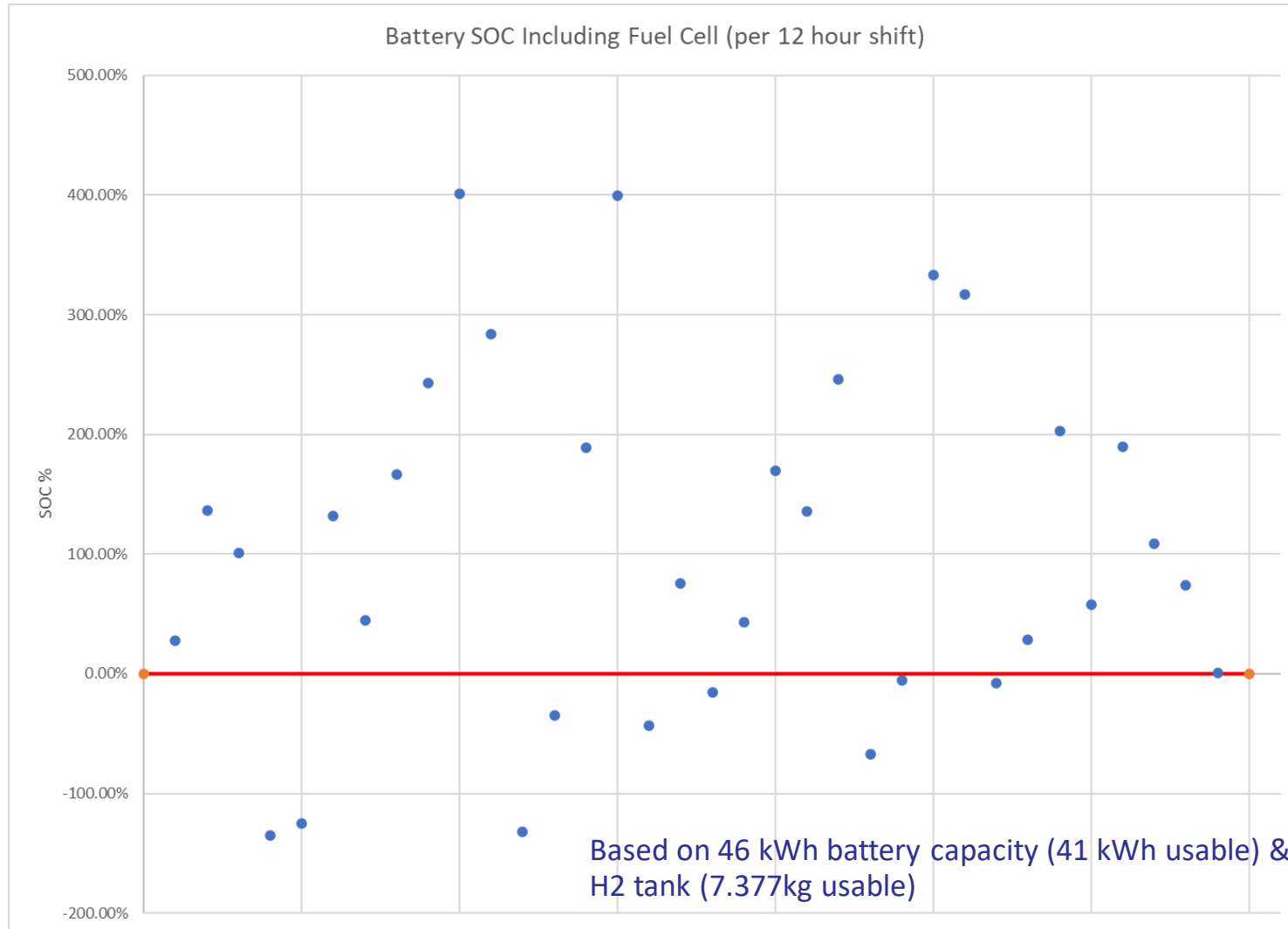
The average distance covered (per 12 hour shift) is only 54 miles with average total engine power consumed/day being 232 kWh, of this, 93 kWh (40%) was idling, some of which was keeping the Ambulance warm and the equipment running.



An EV with no fuel cell would only have enough power to cover 4 of the 34 shifts



Adding a fuel cell with 8kg of H2 would increase this to 25 out of 34 & with refuelling would cover 100% of the energy need



ULEMCo's capability in Range Extension with Fuel Cell technology

- Hydrogen system integration
 - Hardware
 - Packaging
- Hydrogen safety & control
 - Proven patented system control based on H2ICED®
 - Established routes to certification etc
 - Track record with customers on safety
- Fuel Cell balance of plant
 - Hardware
 - Control system integration
 - Cooling; DCDC conversion; optimisation
- Access to Toyota Gen2 (and other commercial suppliers)

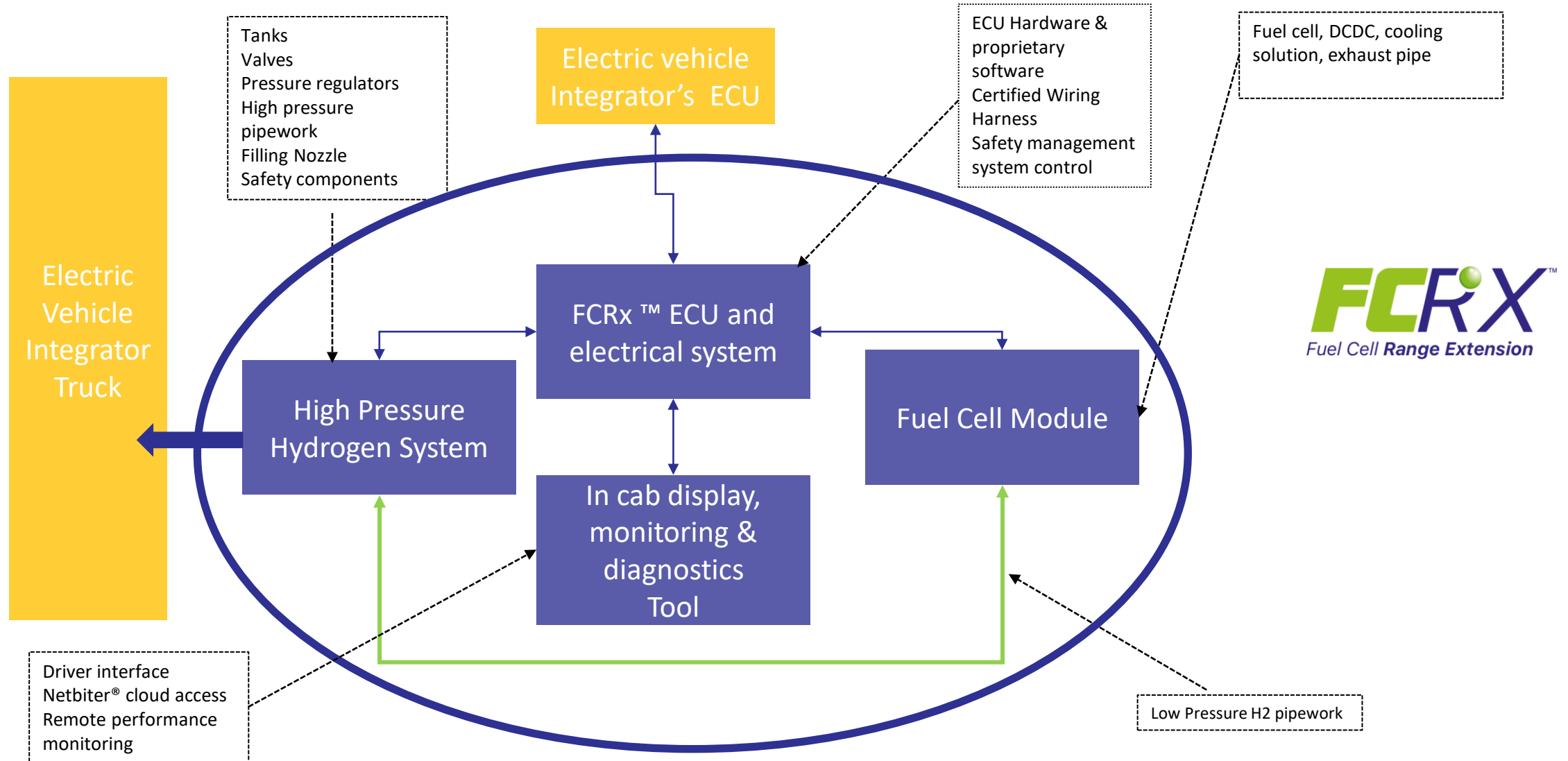
FCR^X
Fuel Cell Range Extension



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The Fuel Cell Range Extension Components



FCRx™
Fuel Cell Range Extension

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The UK's supply chain route for the Toyota Mira Gen2 Fuel cell power module

Benefits of the Toyota Mira Gen 2 Fuel Cell technology for specialist truck applications

- Excellent safety/reliability and support structure for peace of mind during use
- Proven to work in a broad range of operating environments
- Toyota Motor's technical support to ensure that the vehicle system is designed to ensure the durability and efficiency of the fuel cell through it's use (and low maintenance cost).
- The world class power density enables a compact module which is ideal for packaging on a range of vehicle types (that are space and weight constrained).

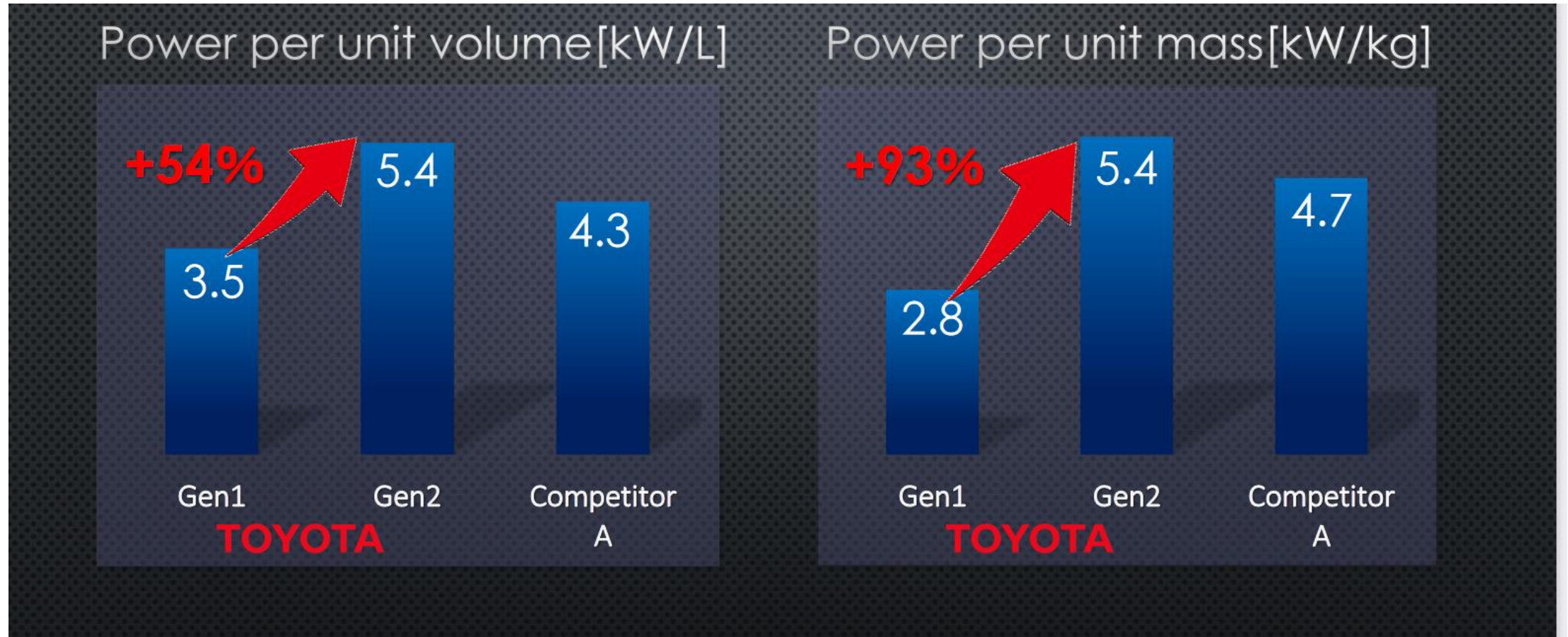


Scaled volume pricing available

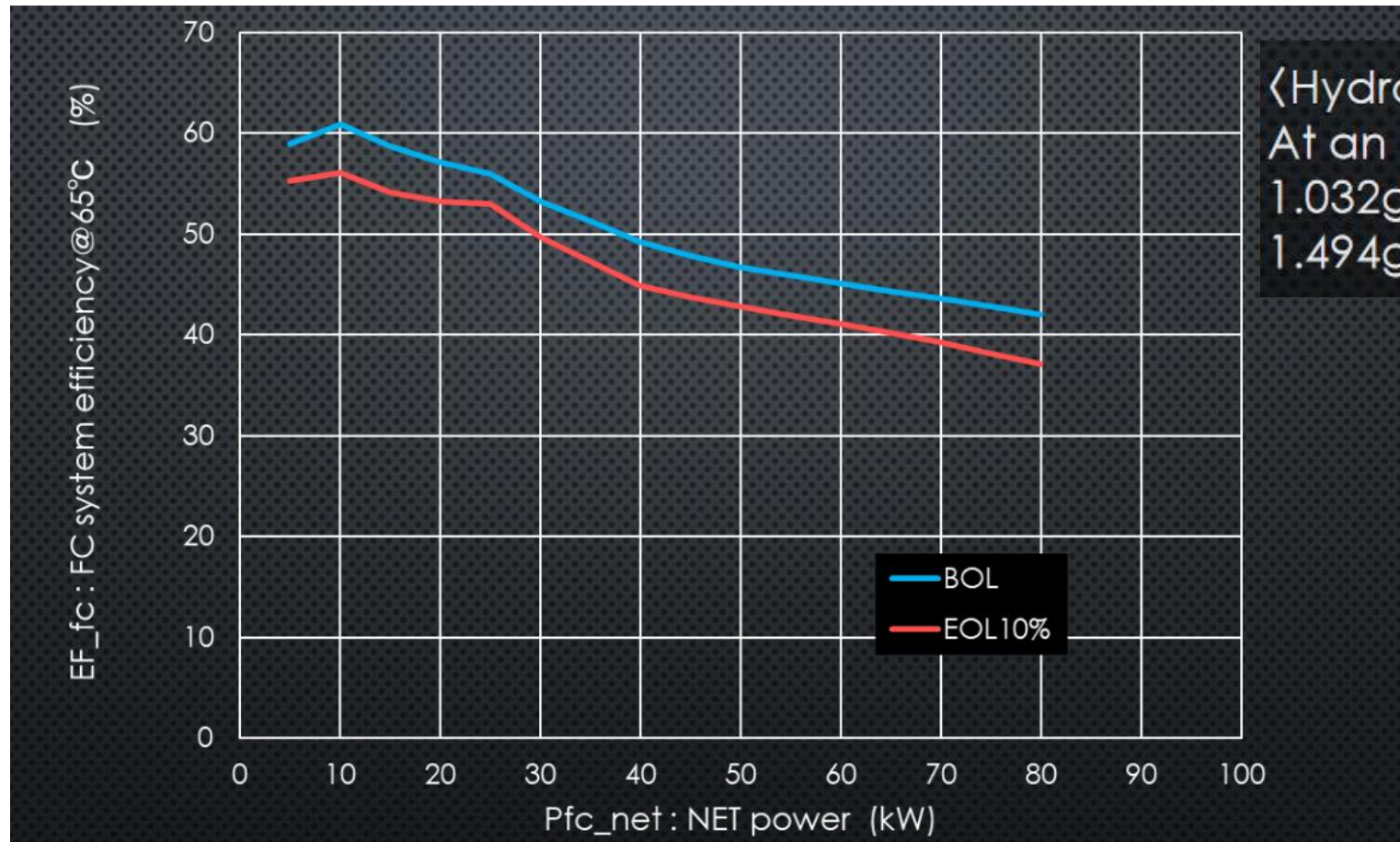
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Fuel Cell Stack Performance

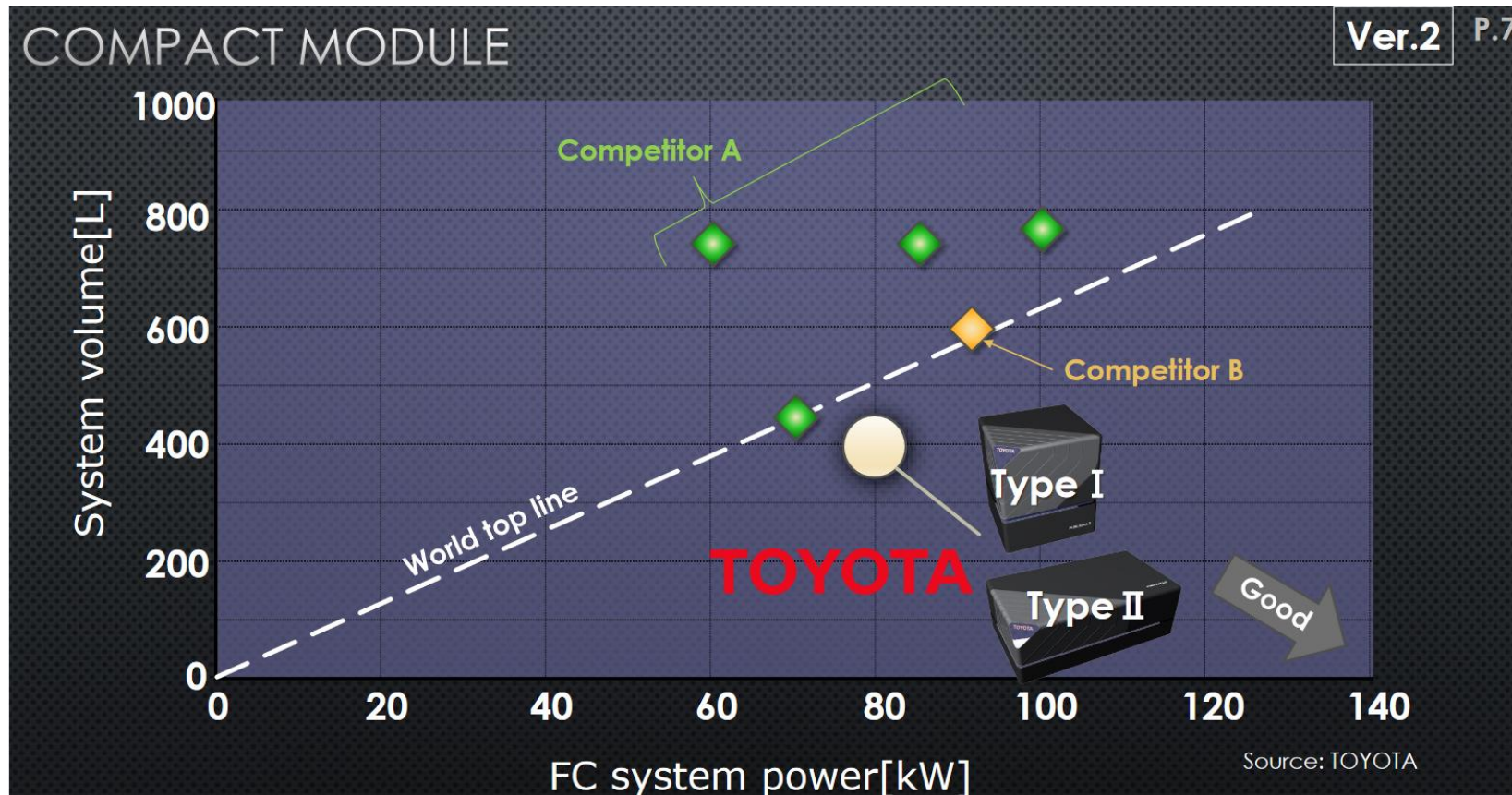


Fuel Cell system efficiency

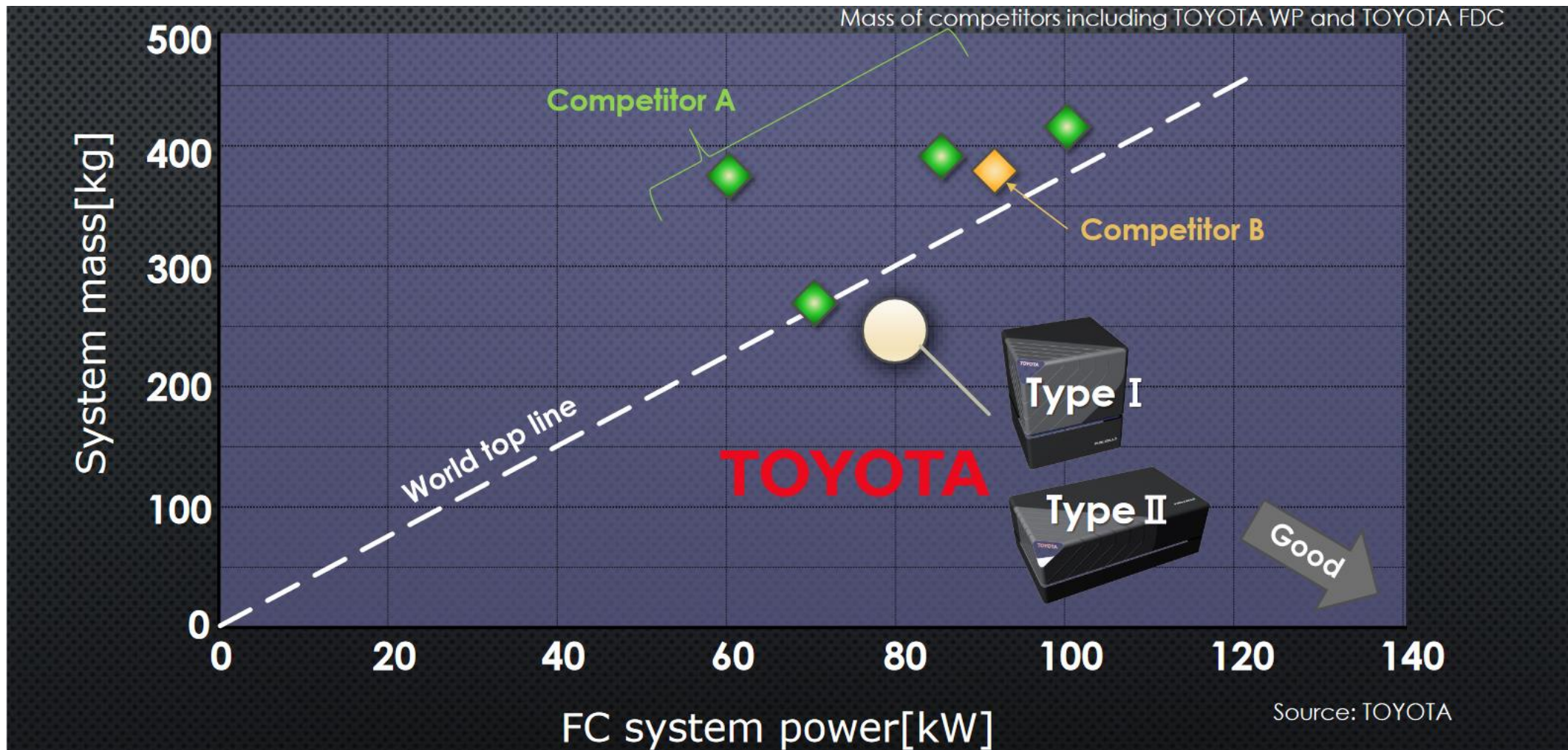


〈Hydrogen consumption〉
At an operating temperature of 75° C
1.032g/sec for BOL 60kW NET
1.494g/sec for BOL 80kW NET

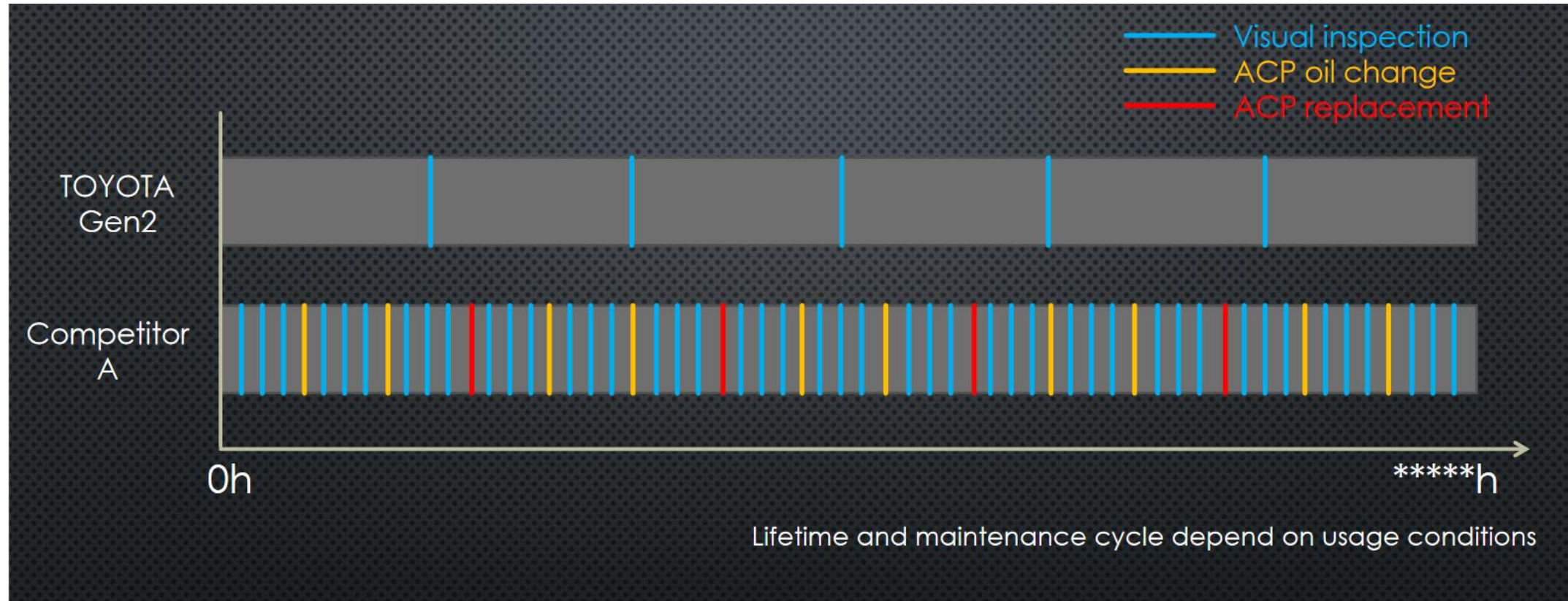
Packaging Options



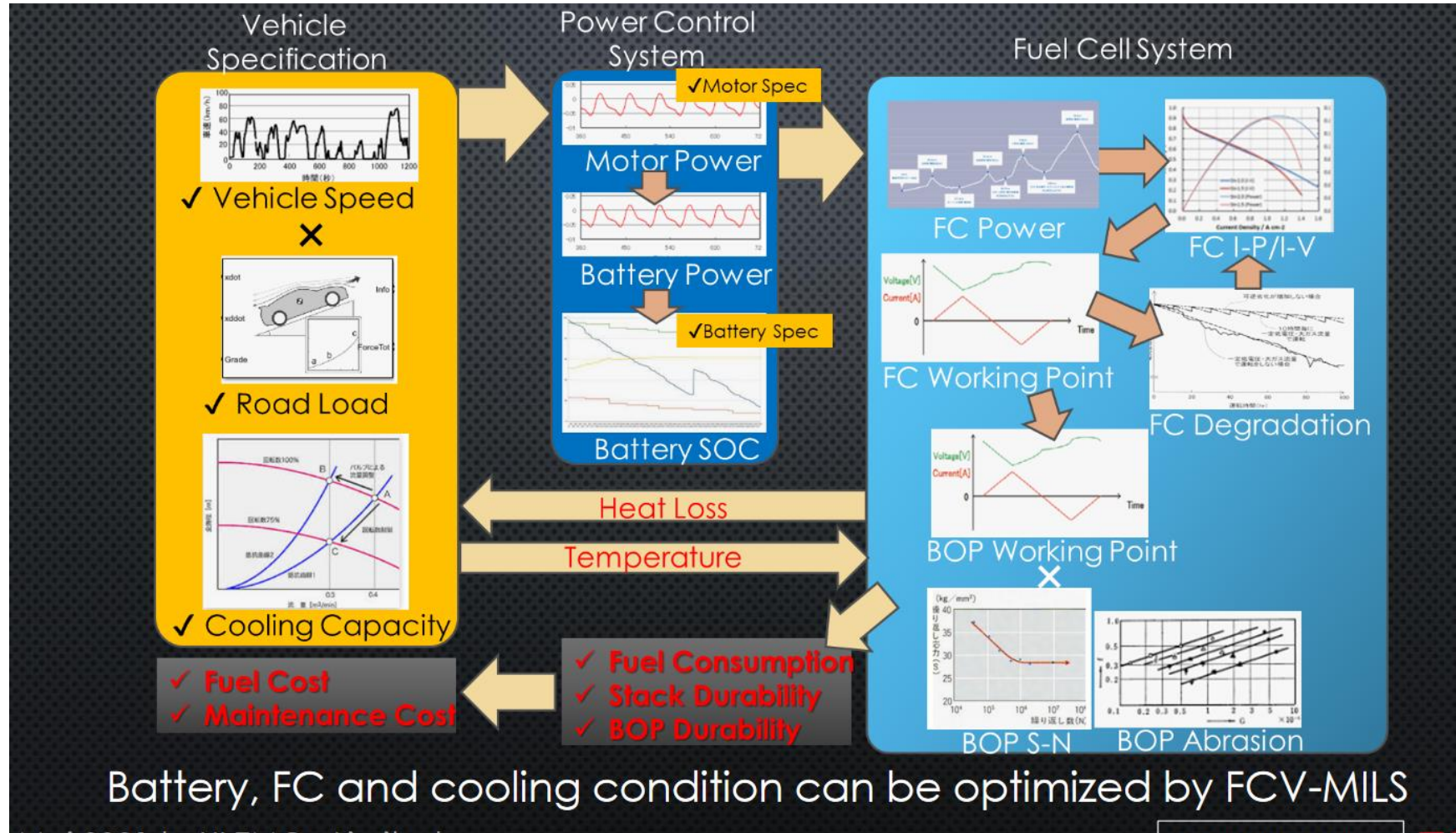
Lightweight



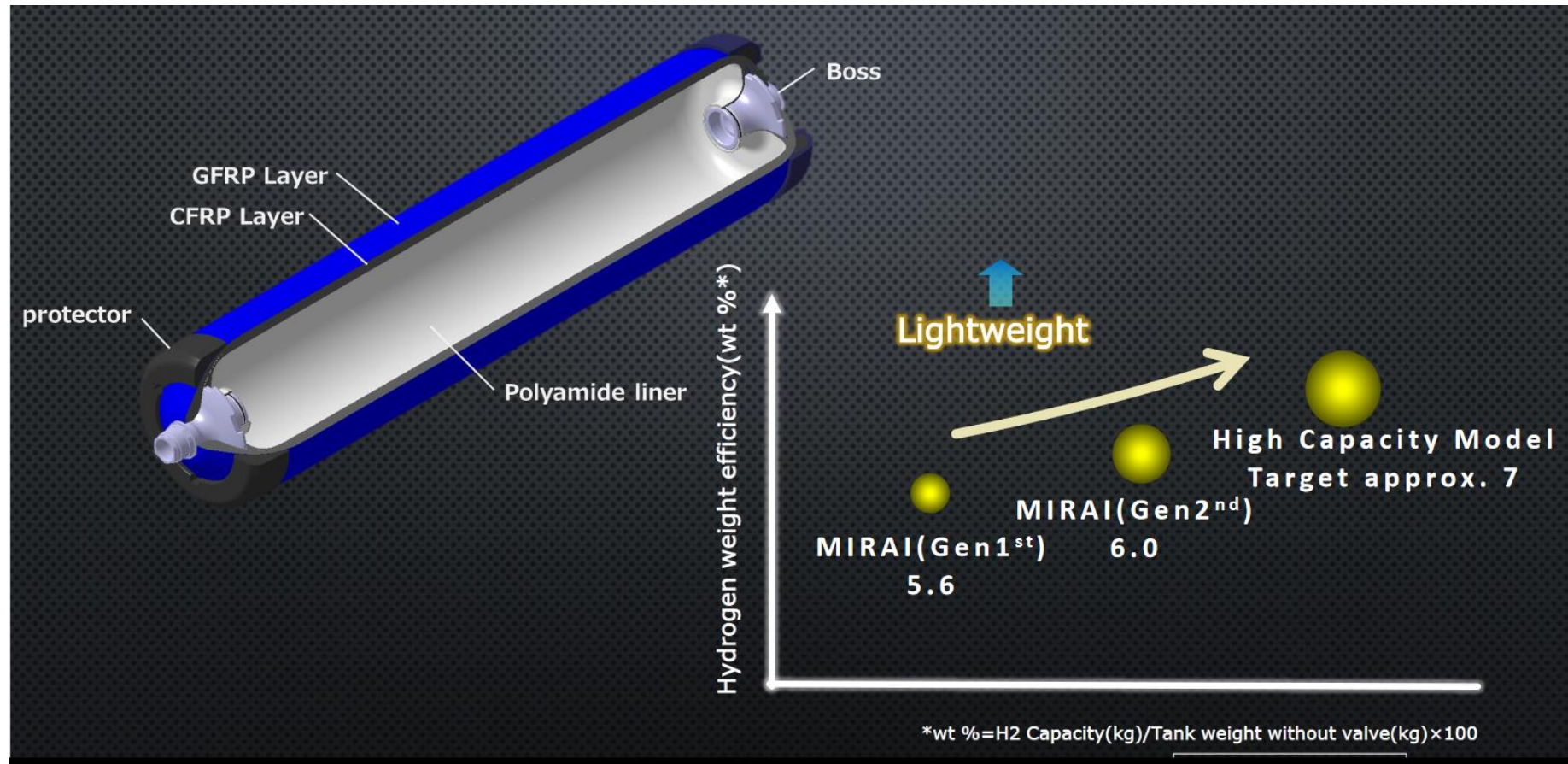
Durable and designed in maintenance



Access to Engineering support



Options for other world class components such as 700 bar tanks



Fuel Cell system Technical Specification

Item	unit	Gen2 spec.	
		Type I :vertical	Type II :horizontal
Rated power	kW	60 ~ 80	
Peak power	kW	60 ~ 80	
voltage range	V(DC)	400 ~ 750	
Power density	kW/L	5.4	5.4
	kW/kg	5.4	5.4
Dimension (L×W×H)	mm	890*630*690 (w/o air cleaner)	1270*630*410 (w/o air cleaner)
Mass	kg	Approx. 250 (w/o air cleaner and W/H)	Approx. 240 (w/o air cleaner and W/H)
Environmental temperature	°C	-30 ~ 45	
Hydrogen specification	—	Type1, Grade D (ISO14687-2:2012)	
Hydrogen pressure	MPa abs	1.1 ~ 1.6	
Coolant specification	—	TOYOTA Genuine FC Stack Coolant (FCC20)	
Coolant conductivity	μS/cm	≦20	
Ingress protection	—	IP67 (without ECU)	



Key Questions for application

- What duty cycle is being considered?
 - Range, power requirements etc
 - Operating conditions
- Refuelling assumptions
 - Balance between Range Extension and H2 refuelling expectations
- Packaging & vehicle design constraints
 - Cargo volume
 - Payload & Weight requirements
- Lifetime maintenance and durability requirements
- Plans for homologation/certification
- Target Cost expectations



And a quick word on another option



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Hydrogen transport solutions for commercial vehicles

Road map to zero in less than 5 years!



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