



Driving a greener future





Hydrogen Vehicle Technology Pipeline

Metroline/Zemo April 2022

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The Wrightbus Story So Far...

Since its inception in 1946, Wrightbus has cultivated a rich history and brand name recognized synonymously with manufacturing quality and innovation.

75 Years of Engineering Heritage

- ▶ A leading industry innovator since 1946 of low emission diesel, hybrid, zero-emission hydrogen and electric buses.
- ▶ First Battery-EV built in 1990s.
- ▶ Transitioned from body-only to integral products in 2007.
- ▶ First single-deck hydrogen fuel-cell EV in 2008.
- ▶ Manufacturer of Iconic Routemaster for London in 2012.
- ▶ Unveiled world's first double-deck FCEV in 2016.
- ▶ Only manufacturer globally to offer single and double-deck hydrogen and electric buses.

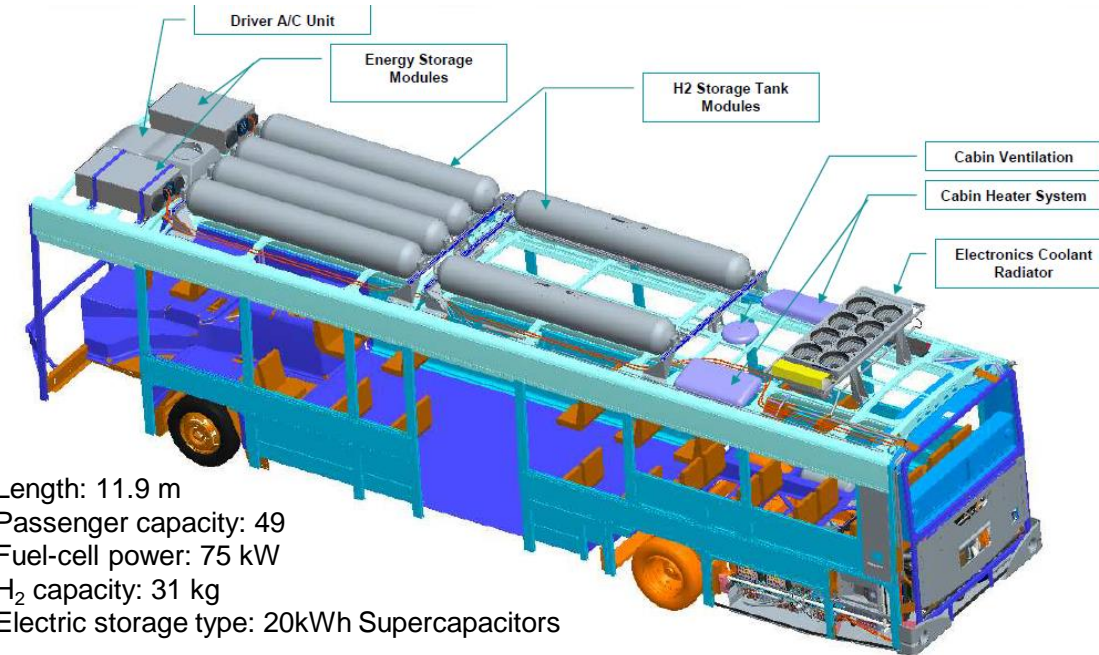
2021 Production
70% Low-Emission
30% Zero-Emission

2022 Production
70% Zero-Emission
30% Low-Emission



Hydrogen FCEV Experience

- ▶ 2008 - eight single-deck FCEBs for London.
- ▶ 12 years in service operating in dense, slow, urban traffic in the centre of the city, and with very long daily duty cycles.
- ▶ In-service achievements:
 - ✓ > 215,000 hours in service.
 - ✓ > 1.25 million miles in service
 - ✓ Daily range of 155-185 miles
 - ✓ Daily operation 16 – 18 hr/day.
 - ✓ Refueling time <10 mins.
 - ✓ Fuel-cell power stack achieving > 35,000 hrs.



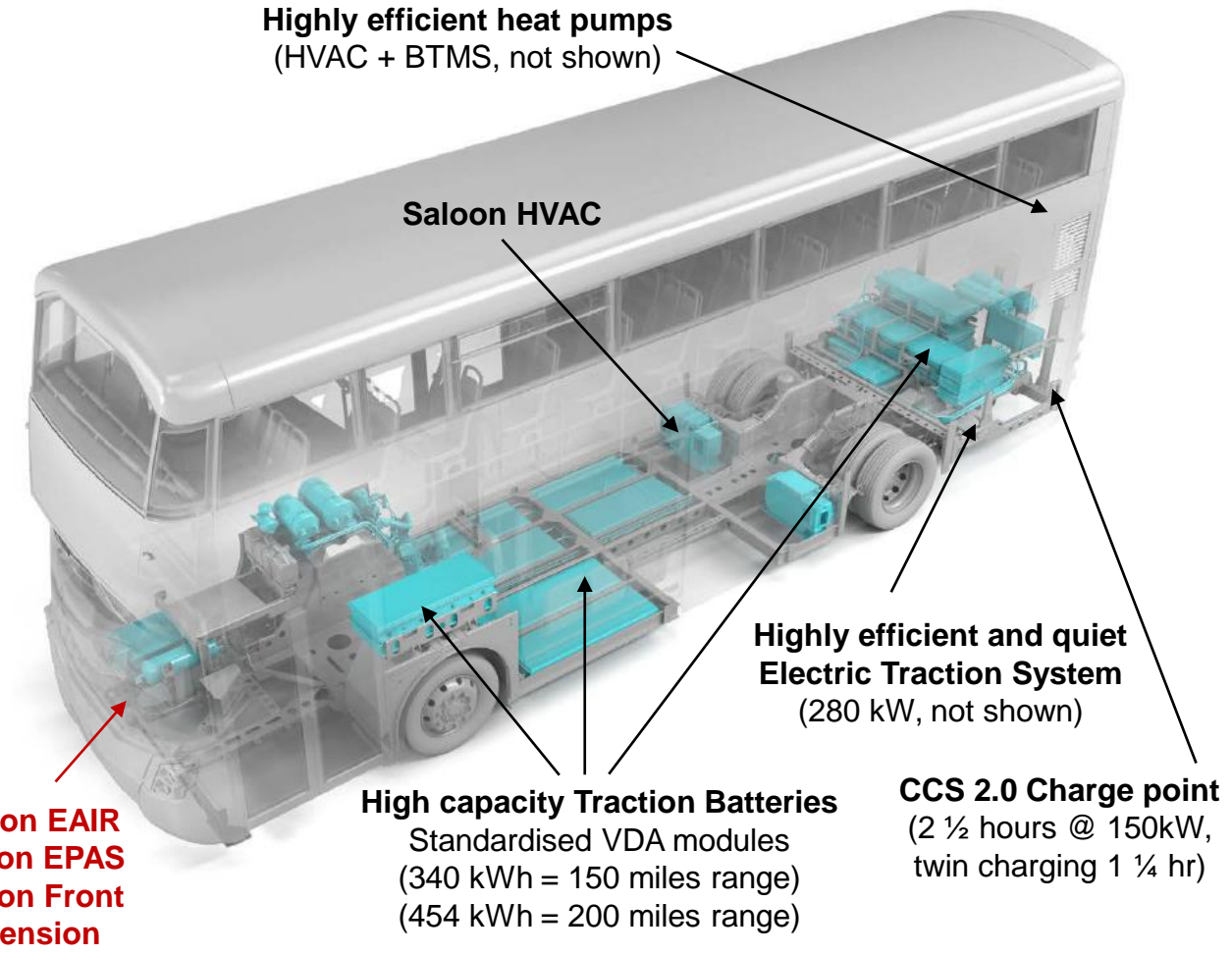
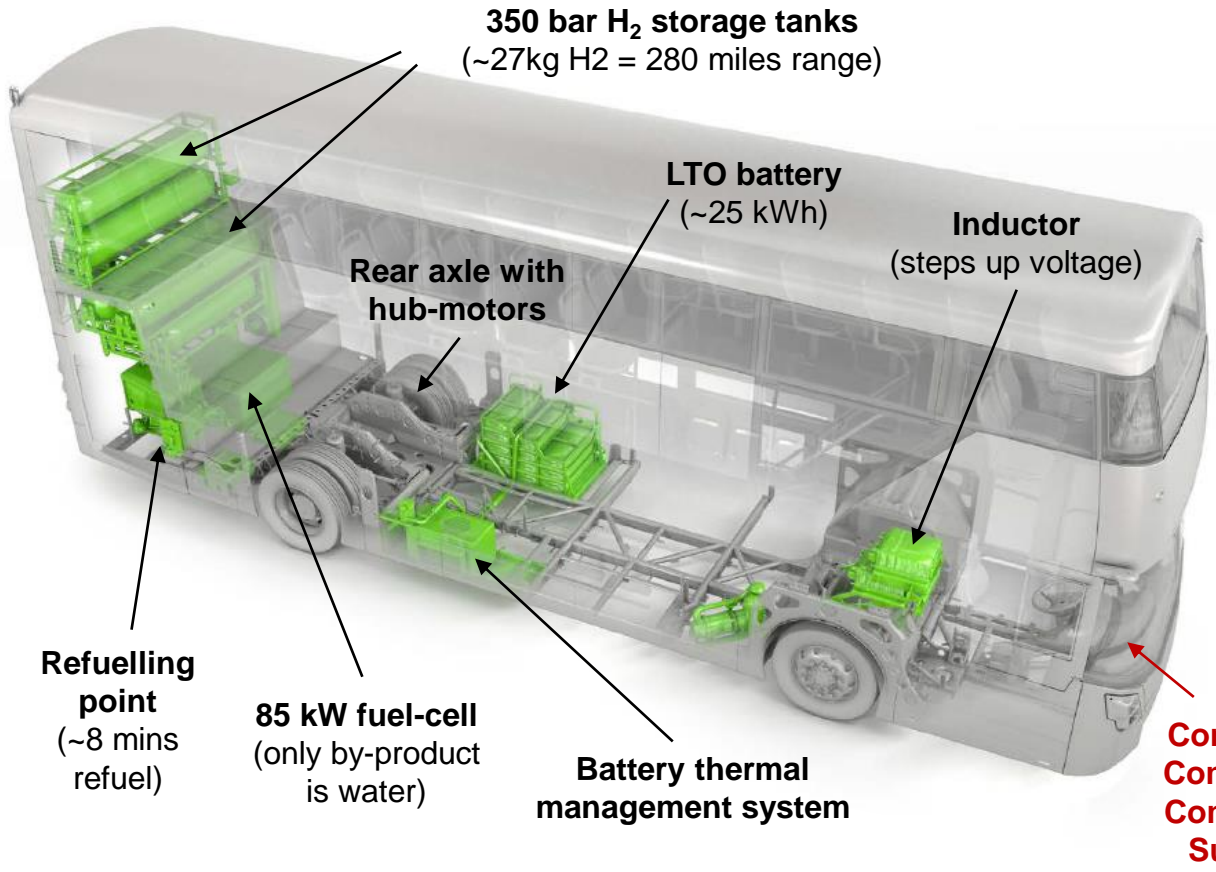
STREETDECK FCEV | HYDROLINER

Hydrogen Fuel-Cell



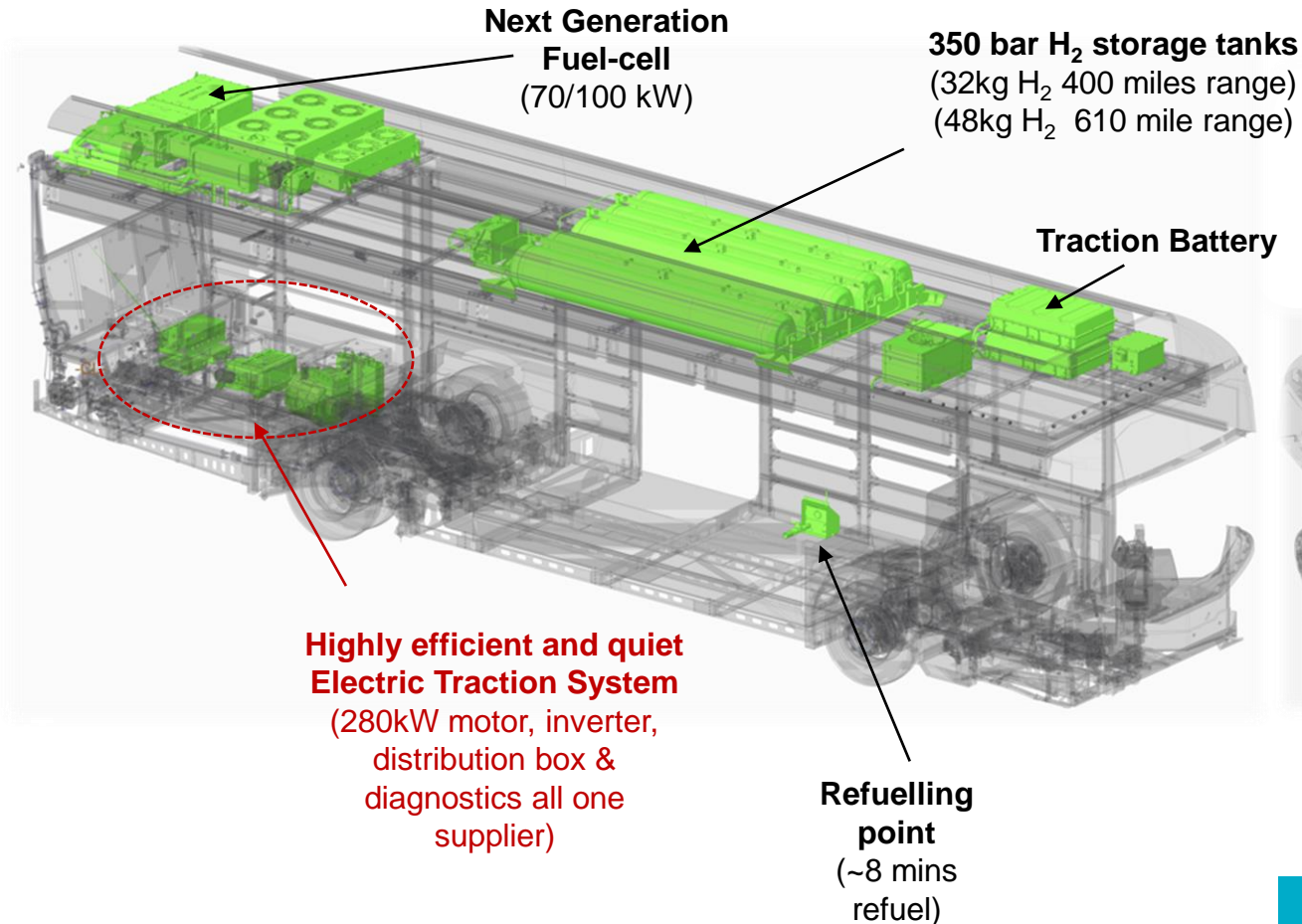
World's first production Hydrogen Double-Deck Bus, designed and built in Ballymena, NI.

Hydrogen Fuel-Cell



Battery-Electric

Hydrogen Fuel-Cell

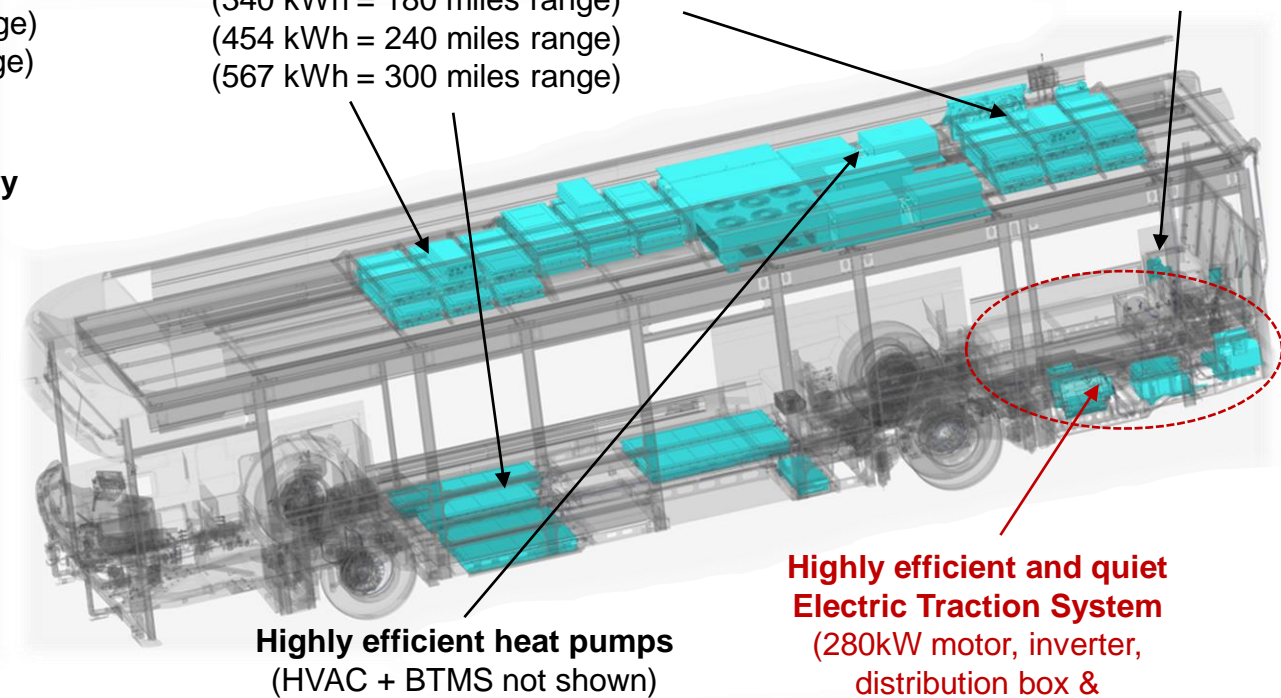


High capacity Traction Batteries

Standardised VDA modules
(340 kWh = 180 miles range)
(454 kWh = 240 miles range)
(567 kWh = 300 miles range)

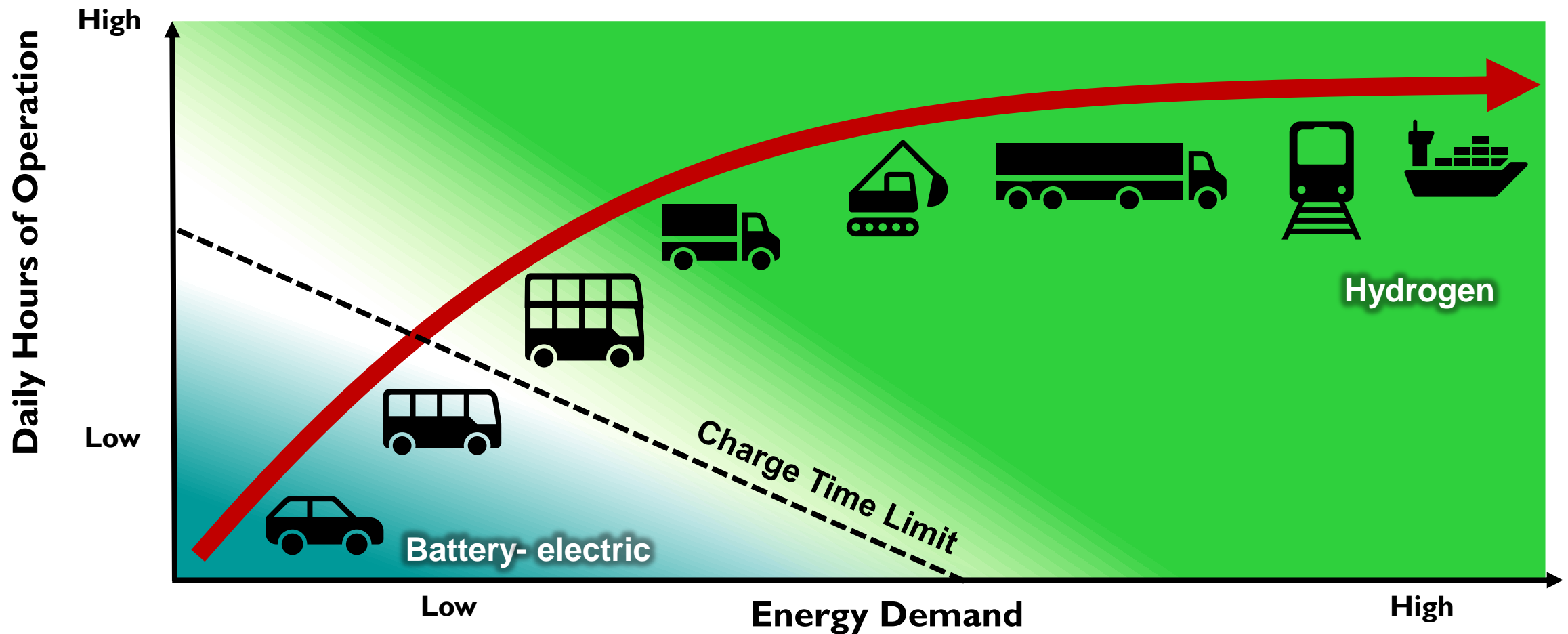
CCS 2.0 Charge point

(2 ½ hours @ 150kW,
twin charging 1 ¼ hr)



Battery-Electric

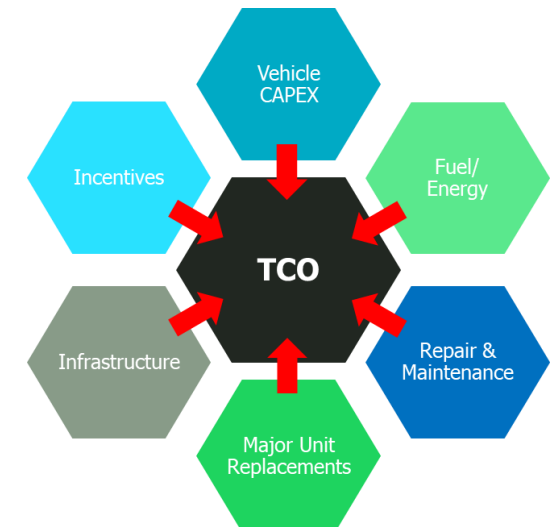
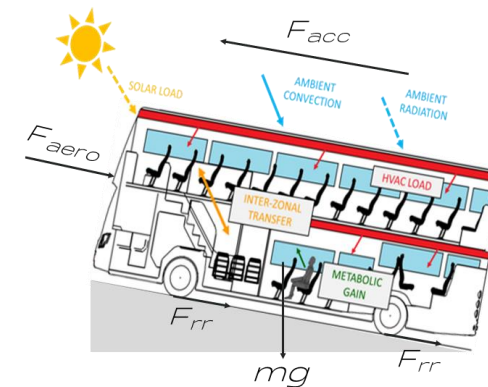
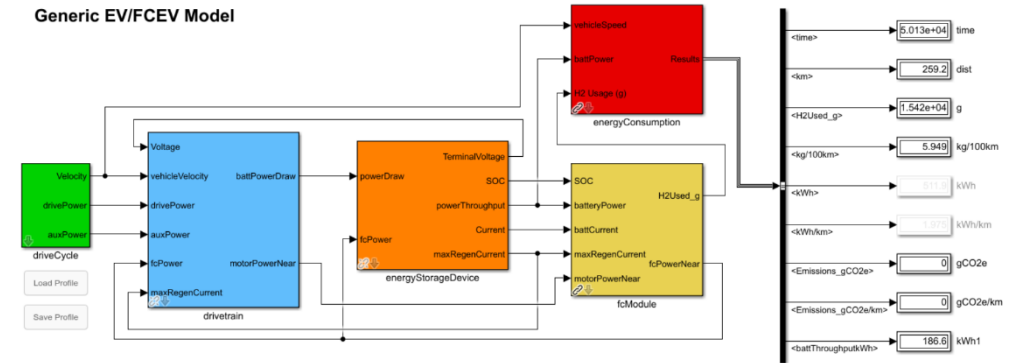
When does Hydrogen Make Sense?



Customer Advisory Tools

Strong Academic Foundations

- ▶ Over 25 years of direct collaboration between Wrightbus and Queens University, Belfast.
 - ▶ Academically robust modelling tools to support our customers in decision-making process for selecting most appropriate zero-emission technology for their bespoke operation and budget.
- ✓ Full route, fleet & depot analysis, including generation of representative bus duty cycles and charge profiles.
 - ✓ Vehicle performance simulations to accurately predict power demands, range and energy consumption per route.
 - ✓ Total cost of ownership and life-cycle carbon forecasts.



Energy Efficiency / Operational Flexibility

	DD FCEV Today	SD FCEV NextGen		
H ₂ storage	27	35	50	kg
Efficiency	7	6	6.2	kg/100km
	2.3	2.0	2.1	kWh/km
Range	386	583	806	km
	241	365	504	miles

	BEV standard	BEV large	
Battery capacity	340	454	kWh
Efficiency	1.1	1.13	- kWh/km
Range	247	321	km
	155	201	miles

- ▶ **BEVs more energy efficient** on less energy demanding routes, but limited on range without costly infrastructure.
- ▶ **FCEVs provide greater operational flexibility** (not route/depot locked), but lower energy efficiency.
- ▶ **Both technologies complementary** – stakeholders should identify best fit to satisfy operational & cost constraints.
- ▶ **Consider daily operational demands**, e.g. minimum mileage, available charging time, # buses + drivers.
- ▶ **Low/zero-carbon sources** of both electricity/hydrogen should always be sourced from where possible.

Safety

Key Considerations when working with Hydrogen machines:-

- ▶ Prevent the formation of ignitable concentrations of hydrogen.
- ▶ Removing all sources of ignition from the facility.
- ▶ A safety regime can be set up in a workshop.
- ▶ The basic principle in the workshop is to respect the fire triangle.

Future of Hydrogen

Falling Total Cost of Ownership

- Step change in costs of fuel-cell modules, H₂ storage tanks and EV drivelines.
- Scaling up production of low carbon H₂ via water electrolysis.
- Increasing fuel-cell stack durability, decreasing maintenance costs.

Improving efficiency

- Control and optimization of powertrain to minimize fuel-consumption.
- Greater use of fuel-cell waste heat for heating interior of bus.

Cross-pollination

- Hydrogen technology is proven on buses.
- H₂ combustion engines or Fuel Cell for coach, ships, trains, off-highway, etc...