Challenges in achieving zero-emission road transport – why fuel cells make sense

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- Intelligent Energy introduction
- Introduction to our APC Project: ESTHER
  - Fuel cell system development and achievement
  - Manufacturing and operations
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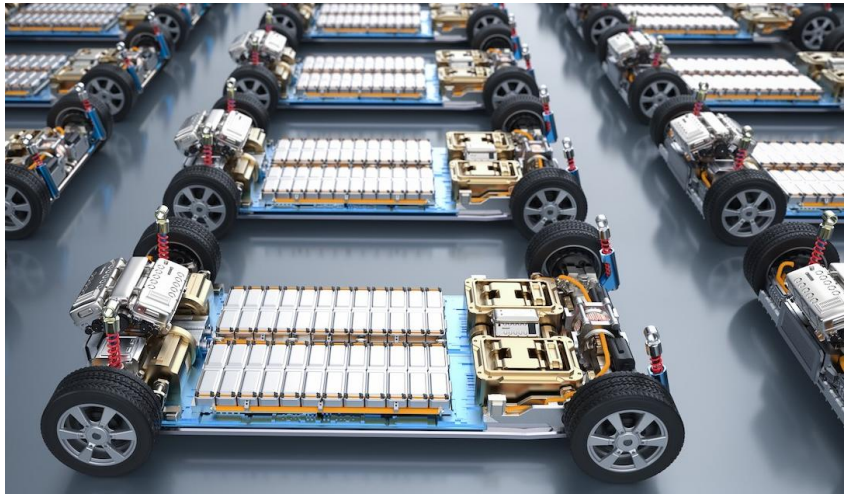
The challenges of achieving zero-emission roads

Main focus globally is on BEVs as the zero-emission solution, however there are several challenges:

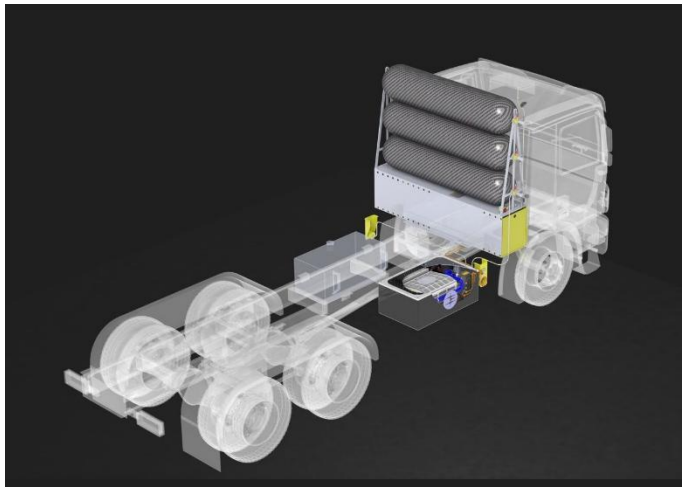
- **Supply chain –** material supply for batteries is a concern, limited sources for lithium, cobalt etc
- **Sustainability –** no economic solutions for recycling batteries
- **Power –** massive increase in the amount of electricity required, and high peak demand to manage
- **Infrastructure –** huge upgrade in electrical infrastructure and high number of charge points needed
- **Range –** high cost/weight of batteries makes longer distance and heavy-duty vehicles impractical
- **Cost –** batteries are an expensive solution, with limited cost reduction potential
- **Peak vs demand –**
  - impractical to store electricity in large volumes
  - issues with managing peak vs demand with increasing non-carbon energy sources

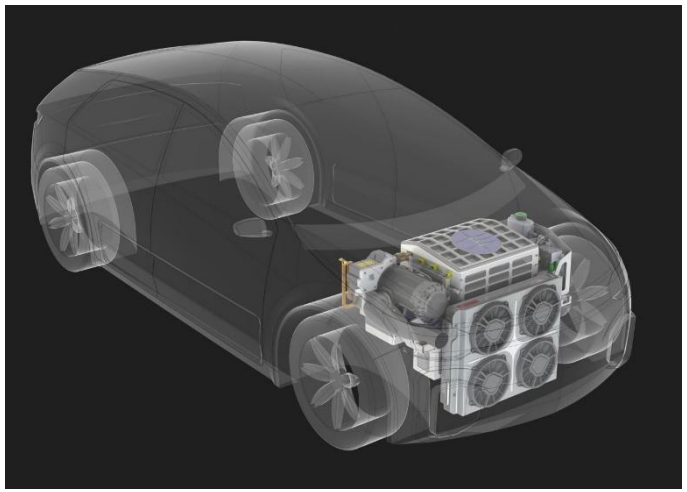


The challenges of achieving zero-emission roads

Fuel cells have the ability to overcome many of the BEV issues:

- **Supply chain –** material supply for fuel cells is not a significant issue
- **Sustainability –** fuel cells are 95% recyclable, and have a positive economic value at end of life
- **Power –** green hydrogen can be generated with off-peak electricity and transported to where its needed
- **Infrastructure –** hydrogen refuelling stations are expensive but serve more vehicles than high-power charger
- **Peak vs demand –** hydrogen can be generated using off-peak electricity that may not otherwise be used
- **Range –** hydrogen fuel cells provide 3x the range of equivalent battery packs
- **Cost –**
  - fuel cells are expensive today but huge cost reduction potential with volume
  - expected to be cost comparable with batteries / IC engines by 2030





Hydrogen vs BEV – key benefits

Passenger vehicle

➢ Hydrogen will outcompete BEVs by circa 2025 for vehicles with very high range (650 km)

➢ Next will come sub-segments such as SUVs and large passenger cars with range requirements of + 500km

➢ For the mid-size car with a 400 km range, FCEVs will reach cost competitiveness around 2030

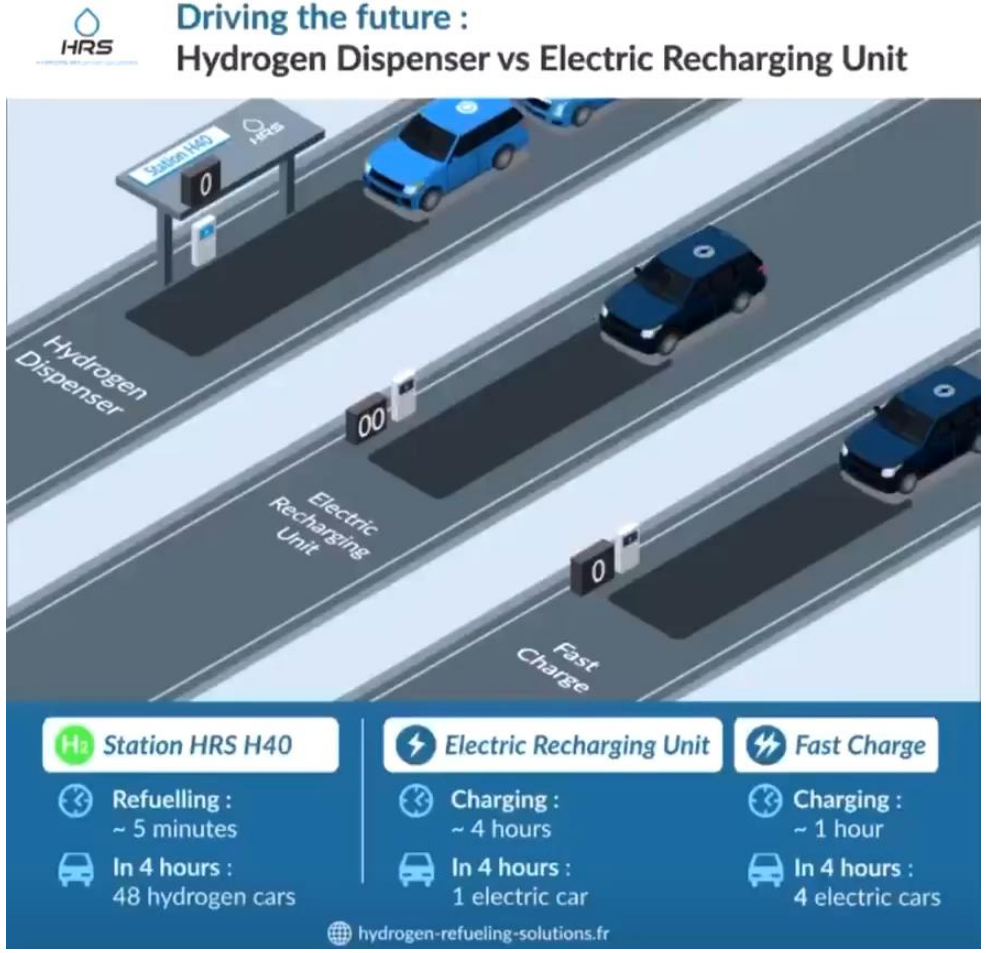
Truck

➢ Fuel costs are a significant component of the cost for trucks, up to 60 per cent of TCO, so low hydrogen cost is key to uptake

➢ Fuel cell trucks could have a comparable TCVO to BEV by 2025

➢ Fuel cell trucks may break even with ICE before 2030 depending on the relative cost of hydrogen vs diesel

Total cost of ownership



Speed of refuelling

Powering the hydrogen future®

Hydrogen fuel cell manufacturer

800W to over 300kW

Automotive, aerospace, telecoms, marine, rail, materials handling, stationary and portable power

23 years' experience

250 employees

1000 patents

10 modular products

Based in the UK

US, Japan, South Korea and China.

Credited with ISO 9001:2015, ISO 14001:2015, ISO 45001:2018 and IATF16949

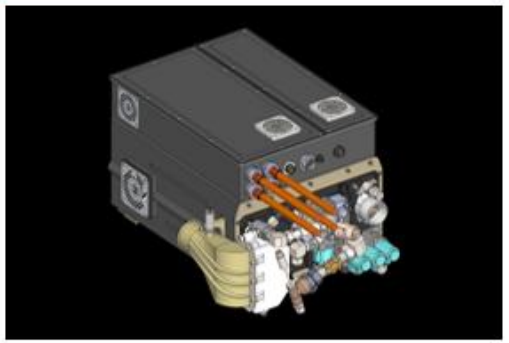
Intelligent Energy®

Zero-emission power from 800W to 1MW

IE-SOAR	IE-POWER	IE-LIFT	IE-DRIVE	IE-FLIGHT
800W – 24kW	**1kW – 32kW**	**1kW – 60kW**	**100kW – 300kW**	**100kW – 1MW**
Lightweight fuel cell modules for drones and VTOL applications	Zero-emission power for construction, standby power and telecoms	Battery box replacement for material handling equipment	Fuel cells for buses, trucks, cars, rail, marine and stationary power	Zero-emission flight for eVTOL, small aircraft and large aircraft










Project ICEBreaker

40-tonne H_2 fuel cell truck targeting weight-parity with a diesel equivalent

- ✓ Intelligent Energy providing 2x IE-DRIVE HD to power a 40t truck
  - Health monitoring, data analysis and predictive service to be optimized through the project
- ✓ Viritech and Horiba-Mira to develop total energy management hardware and software and system digital twin
- ✓ 12 months APC UK funded project, £3m total budget
- ✓ Running demo in September ‘24 (Cenex Expo)

Intelligent Energy®

VIRITECH

A HORIBA COMPANY MIRA

Project ESTHER

Intelligent Energy — Develop fuel cell stack and system for heavy duty and passenger car and transition to Tier 1

ALEXANDER DENNIS — Provide FCS requirements for bus

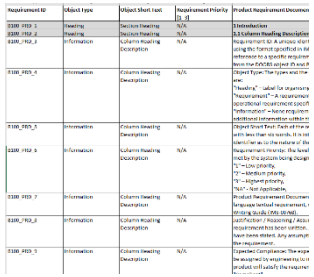
长安汽车 CHANGAN — Develop the skills to integrate and test fuel cell SUVs

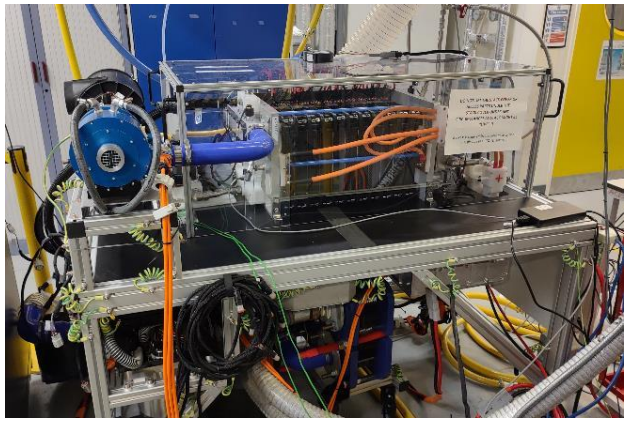
LYRA ELECTRONICS — Develop DC/DC converter product for fuel cells

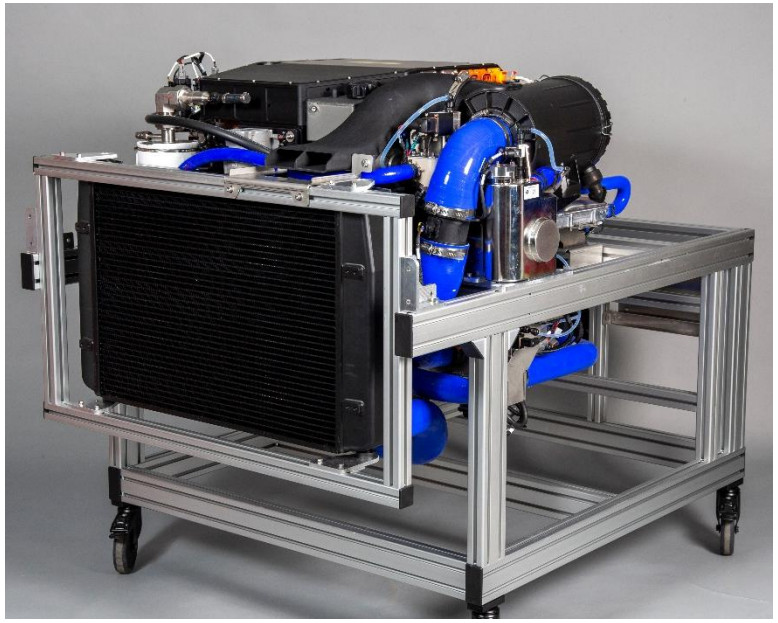
IE-DRIVE 100

Development process

- Develop fuel cell based on IE FC technology
- Fuel cell >100kW – suitable for prime mover application
- Install into Changan SUV for testing



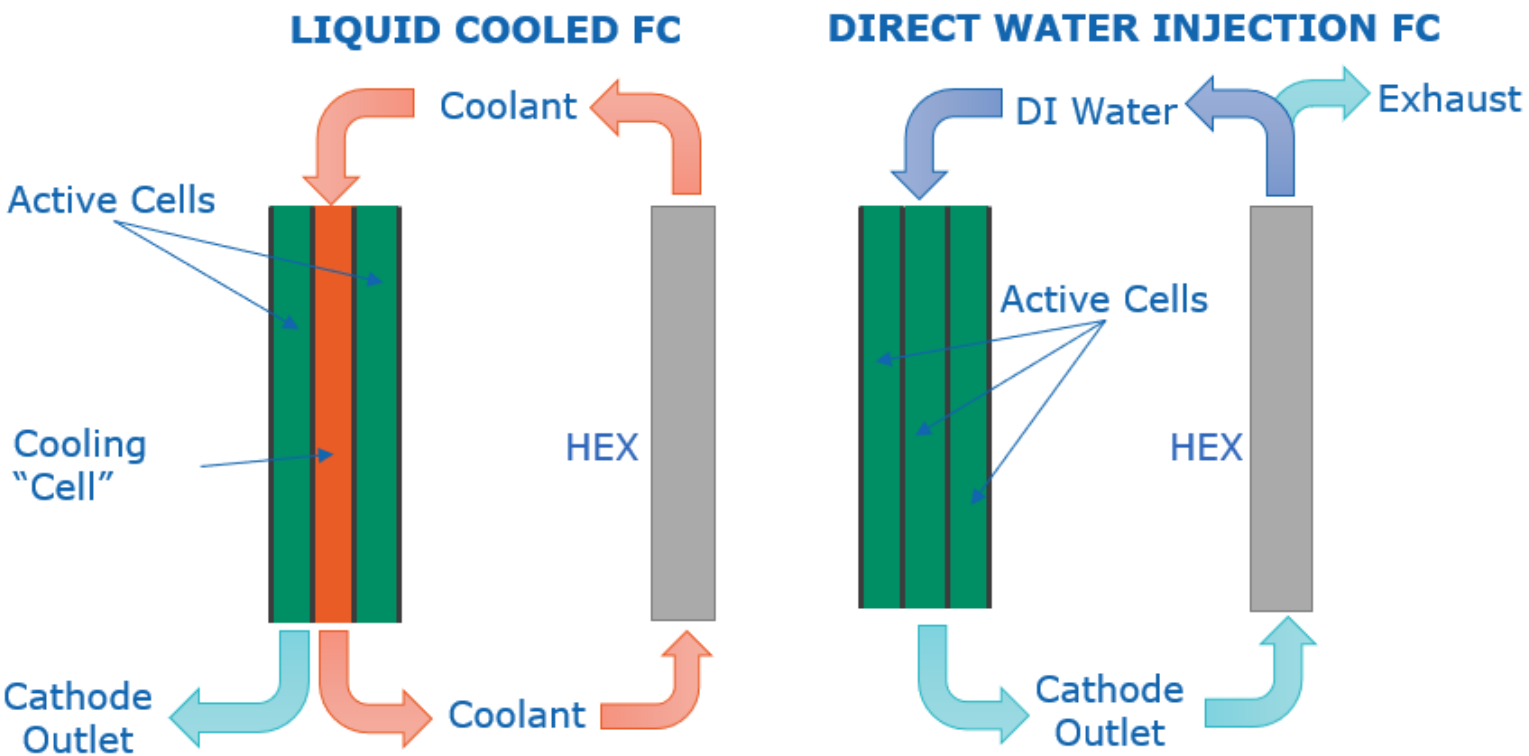




Requirements → Components → Sample → IE-DRIVE 100

IE-DRIVE 100

Direct Water Injection Technology: basic principles and benefits



Features	LC	DI
Stack cooling plate	√	-
Humidifier	√	-
Heat exchanger	√	Smaller*
Coolant pump	√	√
Air compressor	√	√
Coolant storage	√	√

(*) Verified on heavy duty application at 40degC

Benefits	DI
High power density	√
Lower component count	√
Lower cost at volume	√
High reliability	√
Stable efficiency and performance	√

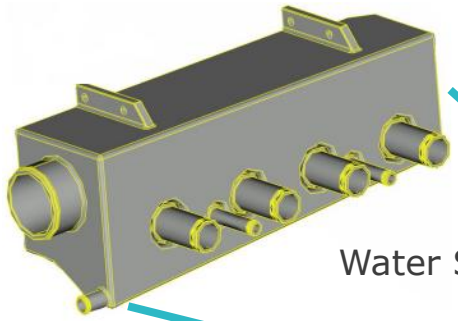
IE-DRIVE 100

Development and achievement

- IE-DRIVE 100 samples built; trial vehicle fit completed successfully
- IE-DRIVE 100 commissioning underway on IE test stand
- Integrated into Changan SUV for road trials

IE-DRIVE 100

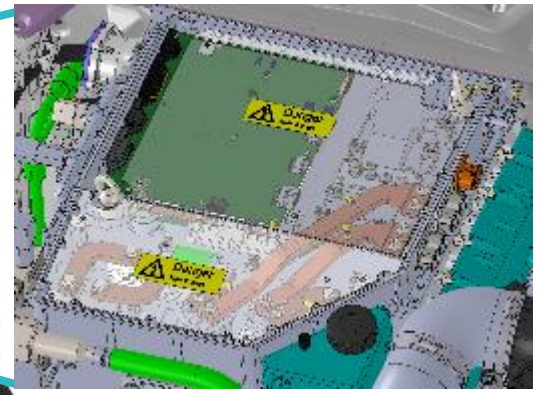
Development and achievement



Water Separator

Hydrogen Recirculation

HV Module



Air Filter

Primary Coolant Module

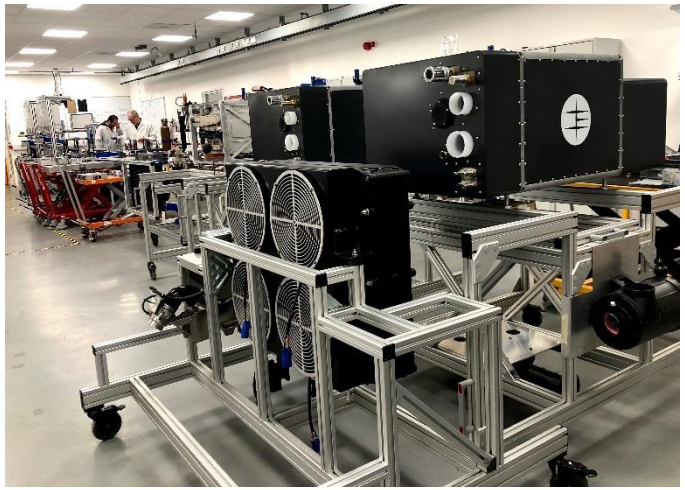
Air Compressor

Air Cooled Condenser

IE-DRIVE 100

Manufacturing and operations

- Fuel cell low-volume assembly line designed and installed
- Line supports DRIVE 100 and HD100 assembly, also compatible with IE next generation stack
- Quality systems achieved ccompliance with **IATF 16949**



IE-DRIVE

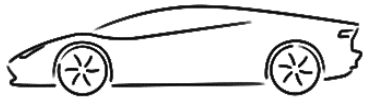
Fuel cells for passenger cars and vans

IE-DRIVE 100

Engine block' format means the system is ideal to fit into existing vehicle designs

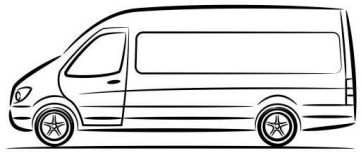
>110kW peak power matched to passenger and light commercial vehicle applications

Up to **70kW continuous power** output depending upon chosen vehicle cooling system design



Passenger car

SUV



Light Commercial Vehicles

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IE-DRIVE

Fuel cells for HD trucks and buses

IE-DRIVE HD100

Compact self-contained unit to allow **easy integration for heavy duty** vehicle applications

100kW net power output through life, ideal for bus and truck applications

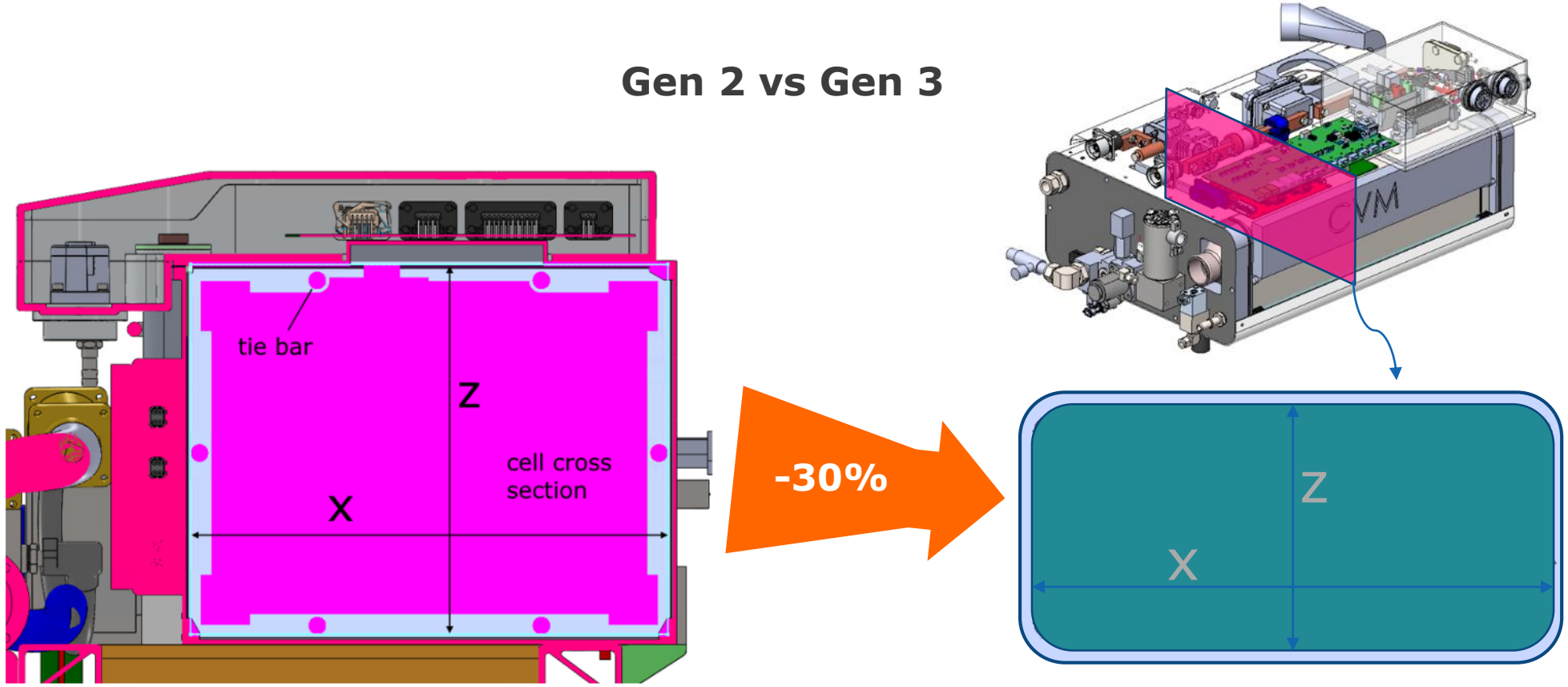
Modular, multiple systems can be operated in parallel to achieve 500kW+

Bus & Coach | **Truck & Van** | **Off-highway** | **Stationary** | **Marine** | **Rail**

Next steps...

Intelligent Energy is already developing the next generation of fuel cell stack technology, our Gen 3 product:

Gen 2 vs Gen 3



Any questions?

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