

A wide-angle photograph of the Earth's horizon from space, showing the curvature of the planet, the blue atmosphere, and the dark surface with scattered white clouds.

# HYDROGEN JOURNEY, NEW CHALLENGE AT EVERY STEP WE TAKE

NET ZERO POLICY TO NET ZERO APPLICATION

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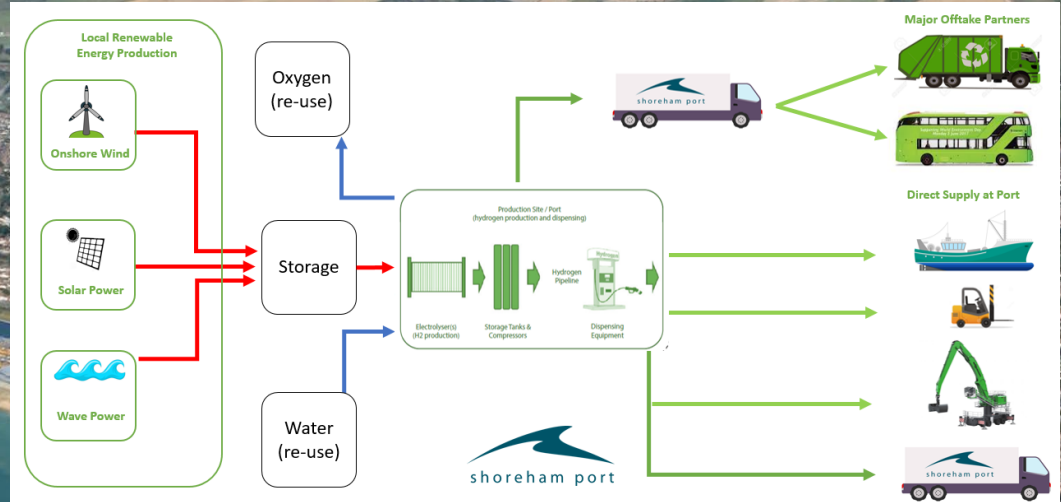
Ing. Bc. Joanna Richart MCIP, CEng, MBA

# GREEN ENERGY HUB- SHOREHAM PORT

**STEP 1**  
VISION AND POLICY  
ALIGNMENT

**STEP 2**  
ENERGY PLANNING  
& SUPPLY

**STEP 3**  
IMPLEMENTATION  
AND APPLICATIONS



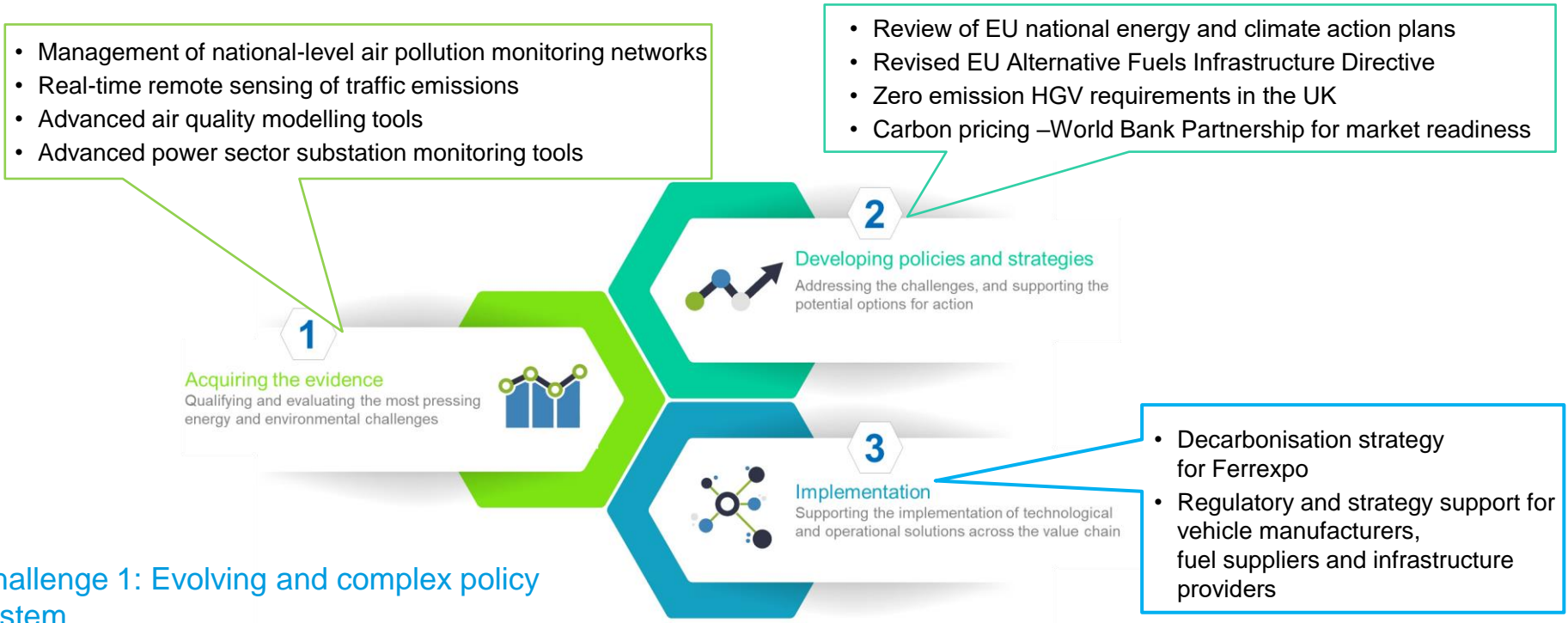
## LET'S START WITH A QUESTION



|      |  |   |
|------|--|---|
| ETS  | Emission Trading System                    | Include the production of <b>hydrogen</b> with electrolyzers                      |
| CBAM | Carbon Border Adjustment Mechanism         | Import levy depending on <b>the emission content</b> of production                |
| ETD  | Energy Taxation Directive                  | Preferential tax rates for the use of renewable and low-carbon <b>hydrogen</b>    |
| AFID | Alternative fuels infrastructure directive | Alternative fuels infrastructure, including refuelling points for <b>hydrogen</b> |
| RED  | Renewable Energy Directive                 | Extending the EU-wide certification system use of renewable <b>hydrogen</b>       |

### Challenge 1: Evolving and complex policy system

# RICARDO'S POLICY WORK - BENEFIT FOR CORPORATE ORGANIZATION



Challenge 1: Evolving and complex policy system

Solved at Ricardo by systematic approach and extensive expertise

## GREEN HUB QUESTIONS...?

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What is the **optimum decarbonization** of your **existing fleet**?

Which **power systems** are most suitable to ensure **competitive** operation and when?

What potential **new power products** will realistically be available and **when**?

Which **fuels** will be commercially viable and when?

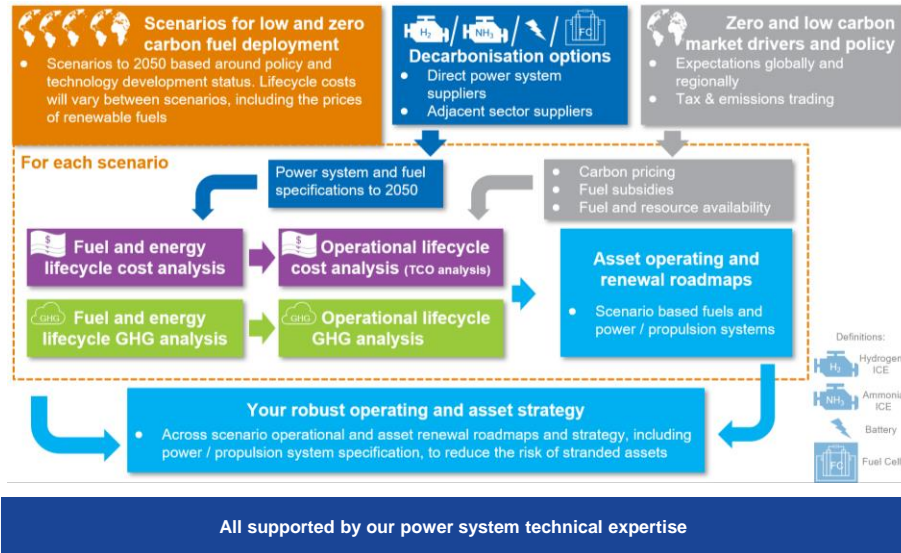
What **specification** of power system is most suitable for my operations?

Which **fuels** and power systems can achieve GHG targets?

Challenge 2: Evolving and complex energy demand

# STRATEGIC PLANNING FOR DECARBONIZATION

## OUR PROCESS: QUANTIFIED SCENARIO ANALYSIS



- Extensive **Life cycle assessment** experience
- **Scenario planning** for future fuels mix and power systems
- Proven **technology roadmap** and **total cost of ownership** assessment process
- **Deep current technical knowledge:** large diesel and gas engines and fuels systems
- **Deep future technical knowledge:** advanced engines, fuel cells and future fuels
- **Market knowledge** to 2035 and beyond

Challenge 2: Evolving and complex energy demand

Solved at Ricardo by systematic approach and extensive expertise

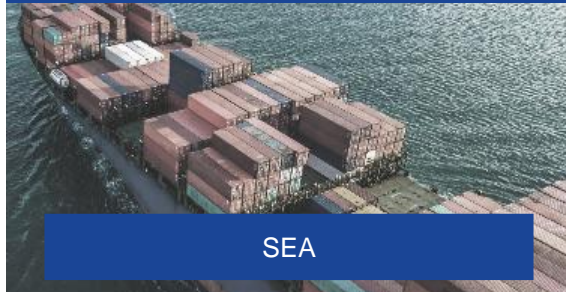
## REAL LIFE APPLICATIONS

- Pass car
- HD truck
- Bus
- Off-Highway
- Rail



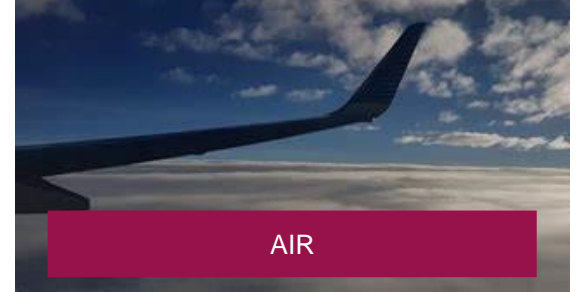
LAND

- Shipping vessels
- Ferry
- Submarine



SEA

- Aero mobility any



AIR

Question: Who was on a hydrogen fuelled “application” ANY?

On land?

On sea?

In the air?

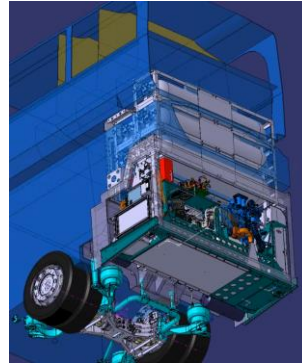
Challenge 3: Demand for bespoke engineering solutions to address needs of multimodal transport

## SOLVING COST CHALLENGE FOR BUS OPERATORS



Project: HYRBUS Innovate UK funded Bus retrofit

Location: Tees Valley



### Objective:

- Develop a demonstrator fuel cell retrofit bus to provide operators with an affordable hydrogen conversion solution

### Benefits:

- 100% decarbonisation
- Affordable: ~ 50% cost of new
- Circular economy
  - Extends asset lives
  - Reduced carbon footprint vs buying new
- Mitigates operator risk of 'stranded diesel assets'

**38,000**

buses currently  
in service

**98%**

are diesel  
powered

Over  
**50%**

are Euro V or  
lower

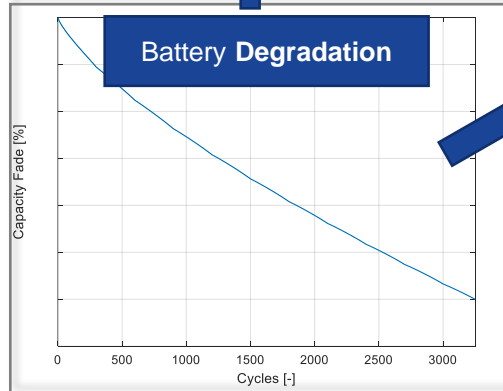
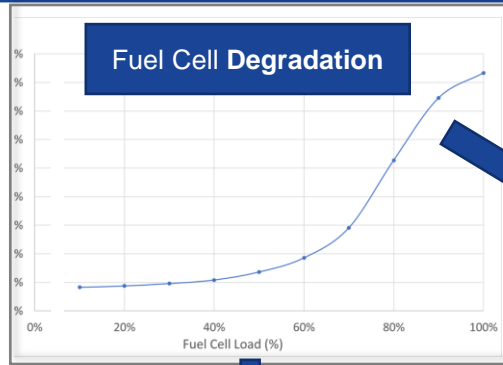
**50%**

are less than 8  
years old

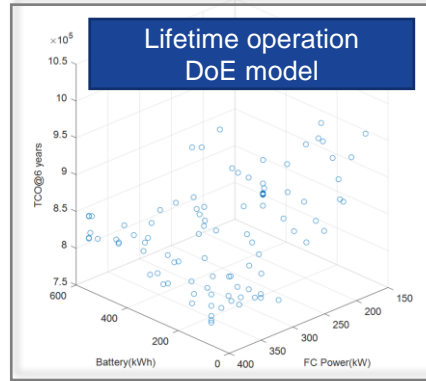
<https://ricardo.com/news-and-media/news-and-press/ricardo-to-engineer-zero-emission-buses-for-uk%E2%80%99s-first-hydrogen-transport-hub>



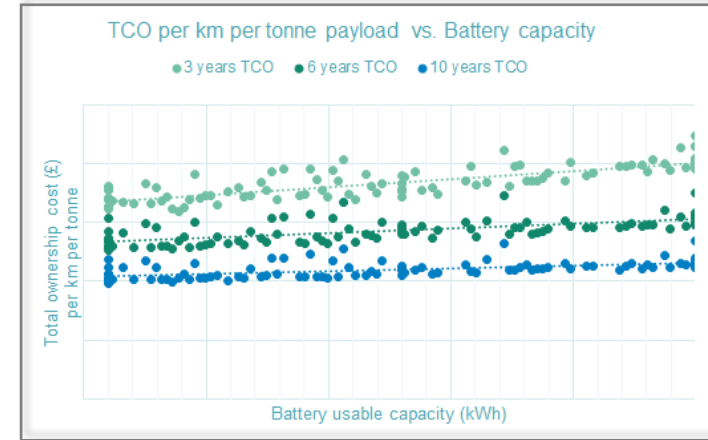
# SOLVING COST CHALLENGE - TCO



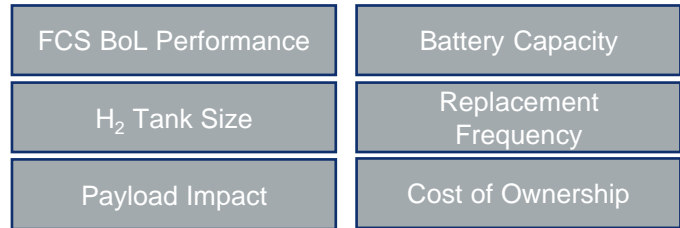
Impact of driving profile on degradation model included with specification ranges



Responses to each factor can be observed to understand trade-offs between TCO & payload per km driven

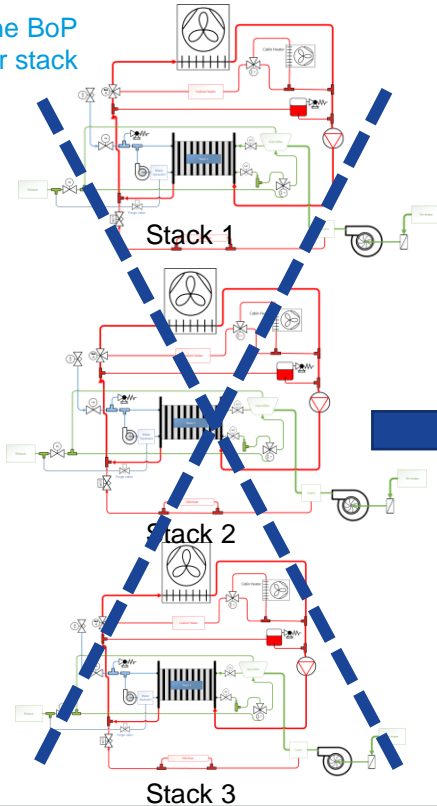


Incorporating degradation model to define recommended Beginning of Life (BoL) system for optimum TCO

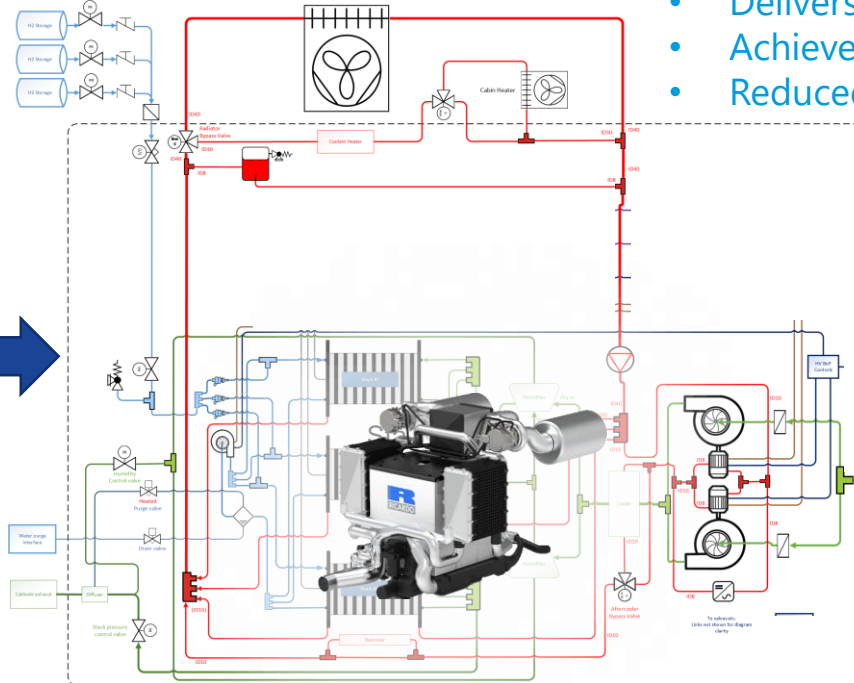


# SOLVING SYSTEM OPTIMIZATION CHALLENGE – SIZE & WEIGHT

One BoP per stack

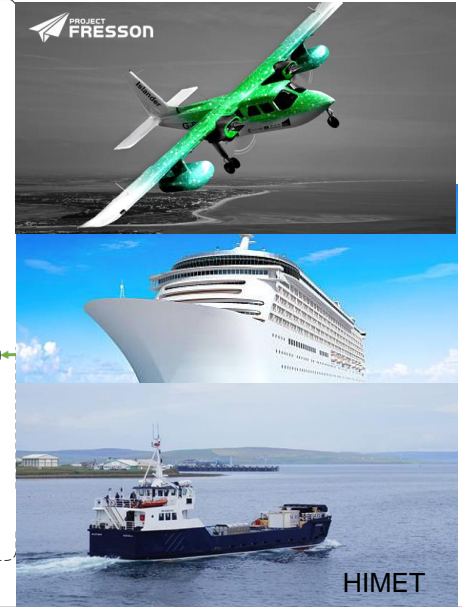


One BoP per multiple stacks

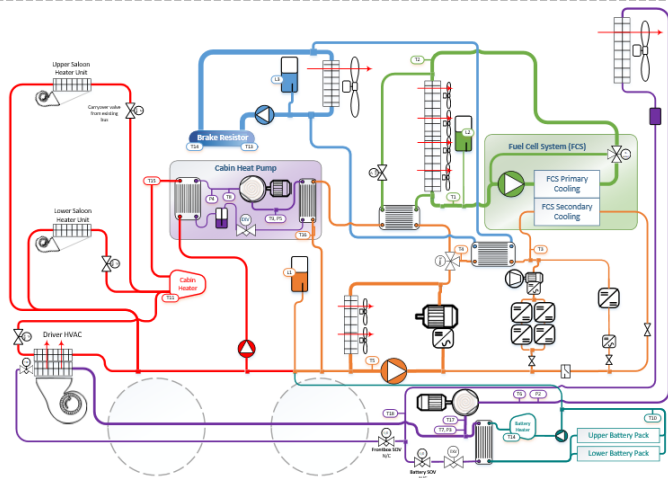


Bespoke BoP:

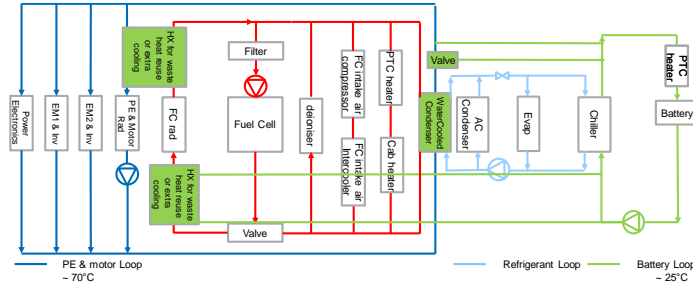
- Delivers higher power
- Achieves higher efficiency
- Reduced volume/weight/cost



# SOLVING SYSTEM OPTIMIZATION CHALLENGE - THERMAL

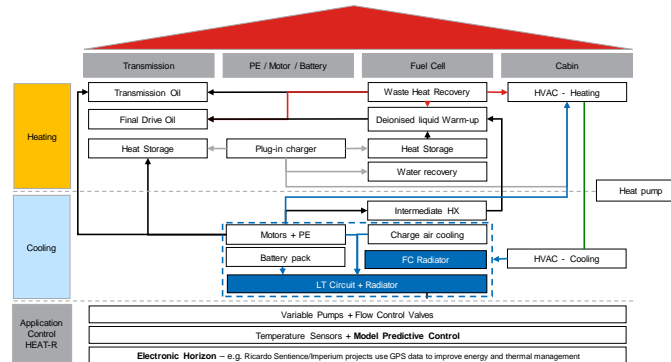


- Balance heating, cooling (fuel cell, battery, electric drive) and other attribute requirements
- Coupling cooling circuits - integration/combination of functions
- Advanced thermal control energy consumption management
- Multi-temperature cooling circuit



**Benefits of using Model Base Development:**  
 Reducing project cost by up to 20%  
 Reducing development time by up to 30%

## Integrated Thermal Management



**Benefits of using ITM with MPC\* & electronic horizon:**  
 Improving EV range by up to 25%  
 Managing heat rejection within packaging & NVH constraints

## SOLVING MARKET ACCEPTANCE CHALLENGE

### Phase 1 FY 21

- One **H2 ICE test facility** – use existing test cell
- Tube trailer fuel delivery model
- Available as soon as fuel supply secured.

### Phase 2 FY 22

- One **H2 FC propulsion system** test facility – convert existing building with a new modular test chamber
- Extension of existing tube trailer delivery model

### Phase 3 FY23

- Scale-up phase for increased capacity and capability to meet customer needs in the future

Ricardo hydrogen enabled test facilities to support new technology validation and market approval.



# 20+ YEARS OF EXPERIENCE IN FUEL CELLS

## TMI

Delivered product specification, new BoP and cost reductions for 1kW truck APU - SOFC and reformer



**Toyota Portal Alpha**  
Integration of 2 x Mirai fuel cell systems into Class 8 truck. Included clean sheet design of H2 storage and electrification of accessories. Specified, selected, sourced, procured and integrated parts and built demonstrator vehicle

## Asian OEM #1

Comprehensive vehicle concept study followed by design, build and commission of fuel cell rig. Conducted fuel cell performance tests

## Asian OEM #3

Designed, built and tested multiple prototype exhaust mufflers for bio-ethanol SOFC vehicle

## Asian OEM #4

Specification of plant and control models

**Porterbrook Rail**  
UK's first mainline H2 fuel cell train. Safety case & cert



## Pax ferry

Scalable H2 FC system for on board auxiliary power



## Cruise ship

Multi-MW FC system concept for cruise ship



2004

2005

2006

2007

2008

2009

2010

2011

2012

2013

2014

2015

2016

2017

2018

2019

2020

2021

**Automotive Supplier**  
Benchmarking for 500W prototype SOFC for vehicle electrical power



**Roads2HyCom**  
Coordinator for project assessing research in fuel cells and



**Asian OEM #1**  
Following fuel cell testing optimisation of control system through simulation of multiple vehicle architectures with max range being primary concern

## Toyota Portal Beta

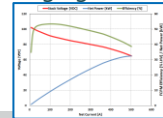
Improved packaging and integration of components. Optimised cooling system and hydrogen storage. Built demonstrator vehicle



**Global OEM**  
FC integration, improved cooling system, build & commissioning support for pre-production HD trucks

## Asian OEM #2

Drive Cycle range simulation, control strategy and packaging for fuel cell REEV



## Aerospace Startup

Fuel cell for aerospace application



## Fuel Cell System retrofit kit for buses

replace Diesel propulsion system by FC kit on existing buses



**ExxonMobil**  
Design and build prototype Pressure Swing Reformer



## Enhanced Fuel Cell System

Consortium developing 40kW FC for automotive. Provided specification and were responsible for sign-off

Challenge 3: Demand for bespoke engineering solutions

Solved at Ricardo by systematic approach and extensive expertise

## OUR TEAM OF EXPERTS



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THANK YOU

# ACKNOWLEDGEMENTS

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- **Project HIMET**, demonstrating hydrogen technologies to accelerate maritime decarbonisation in Orkney, is one of 55 projects selected for funding under the UK Government's Department for Transport's flagship Clean Maritime Demonstration Competition, delivered in partnership with Innovate UK.
- **Project NEPTUNE**, helping the Shetland Islands' maritime industry achieve Net-Zero has received support from the UK Government's Department for Transport's Clean Maritime Demonstration Competition, delivered in partnership with Innovate UK.
- **Project Fresson**, which is delivering the world's first green passenger carrying airline services using hydrogen fuel cell technology is supported by the ATI Programme, a joint Government and industry investment to maintain and grow the UK's competitive position in civil aerospace design and manufacture. The programme, delivered through a partnership between the Aerospace Technology Institute (ATI), Department for Business, Energy & Industrial Strategy (BEIS) and Innovate UK, addresses technology, capability and supply chain challenges.
- **Project HYRBUS**, to develop a hydrogen fuel cell retrofit bus solution, is supported by the UK Government's Department for Transport as part of the Hydrogen Transport Hub Demonstration competition.