

HYDROGEN AND FUEL CELLS

Fuelling the Future Now

CCSHFC
2023

Innovative Printed Circuit Board Fuel Cell Stack and Systems

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7 March 2023

Introduction

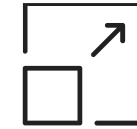
Bramble is a **disruptive electrochemical device manufacturer** that leverages the **global manufacturing maturity, materials and techniques from the printed circuit board (PCB) industry.**

Headquarters near Gatwick Airport, UK, with **40,000 sqft hydrogen fuel cell R&D facility.**

80 employees and continuously growing



Low cost



Scalable



Customisable



Introducing the PCBFC™



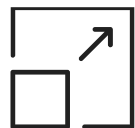
Bramble's fuel cell (PEM, LT or HT) technology, **PCBFC™** is a **low-cost, scalable** solution that can be manufactured in PCB factories across the globe.

Using printed circuit board (PCB) materials and manufacturing techniques, the fuel cells are designed for each unique application. Rapid and scalable processes result in a **simplified BoM** and **customised fuel cells** for a **wide range of applications**.

Traditional Fuel Cell Stack		PCBFC™
Bipolar plates	→	PCB
Endplates	→	PCB
Compression system	→	PCB
Coolant gasket	→	PCB
Current collector	→	PCB
End gasket	→	PCB



Low cost



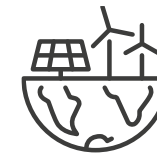
Scalable



Rapid



Customisable



Global



High specific power

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Sectors of Interest - Mobility

Bramble's high-power, liquid-cooled PCBFC™ is applicable to a range of mobility applications.

Marine



In 2023 Bramble is targeting 'Approval in Principle' for a 10kW marinised PCBFC™ system.

Automotive



Bramble is working to demonstrate PCBFC™ in commercial vehicles, non-road mobile machinery and more.

Aviation



Bramble and partners are working to develop a powertrain concept design for an aviation-ready fuel cell.

Genset



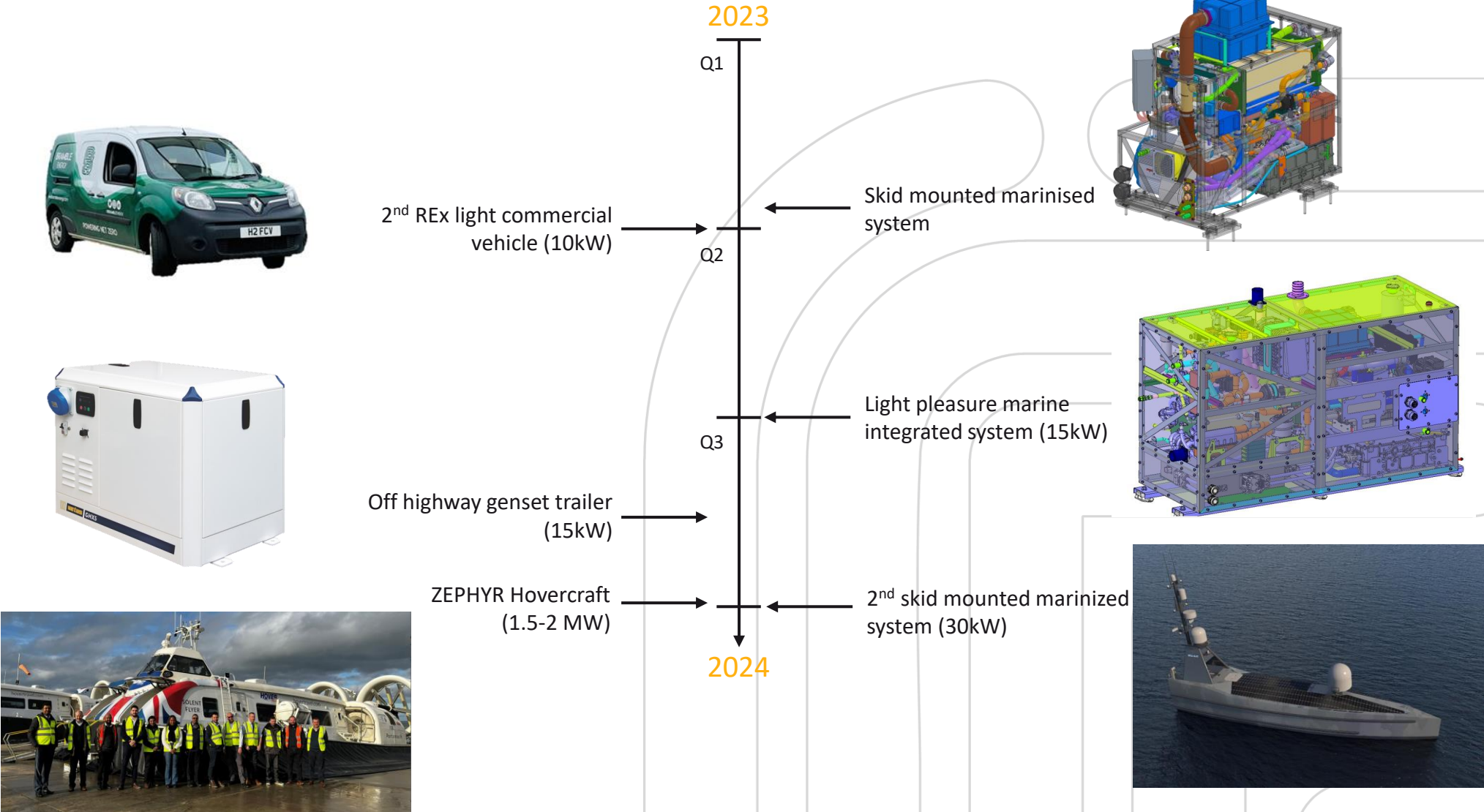
Demonstrator of PCBFC system into a mobile genset for replacing Diesel engine gensets.

Railway



Specific development for railway applications for stack and systems (durability, vibration)

PCBFC™ Demonstrator Timeline



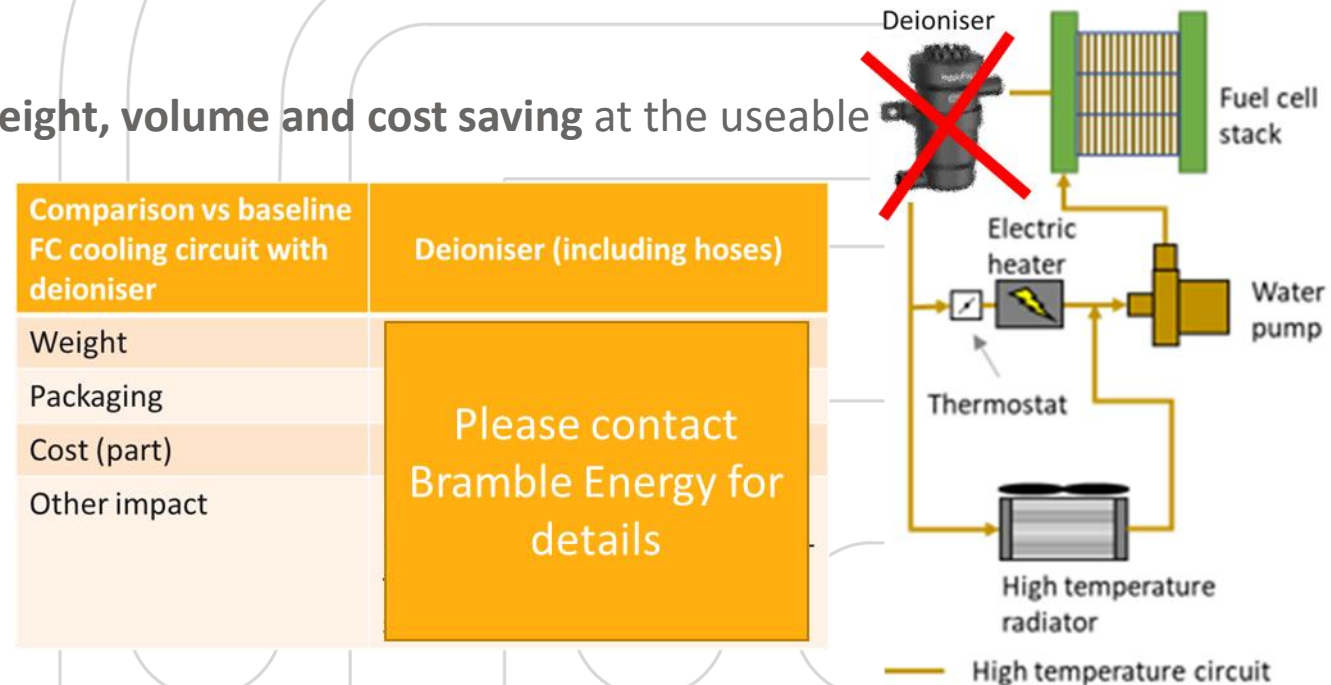
Thanks to Innovate UK and BEIS funding

PCBFC™ System Advantages

The PCBFC™ uses standardised PCB materials, leading to **system level advantages** :

- Bespoke stack voltage / current profiles can allow for higher system efficiencies and the **simplification or even removal of the DC-DC converter, through simplified hybridisation** (for example designing a stack with an 800V output voltage).
- The construction of the PCBFC™ significantly reduces the complexity of the cooling system **by removing the need for the deioniser.**

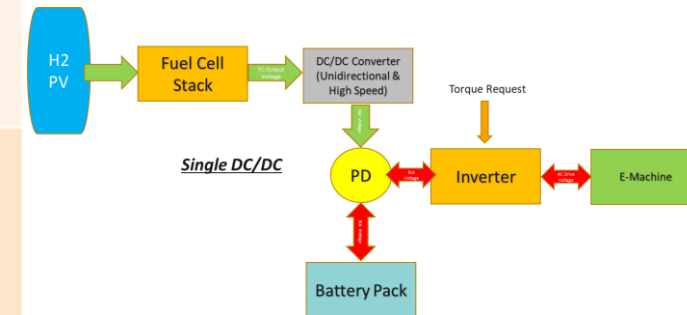
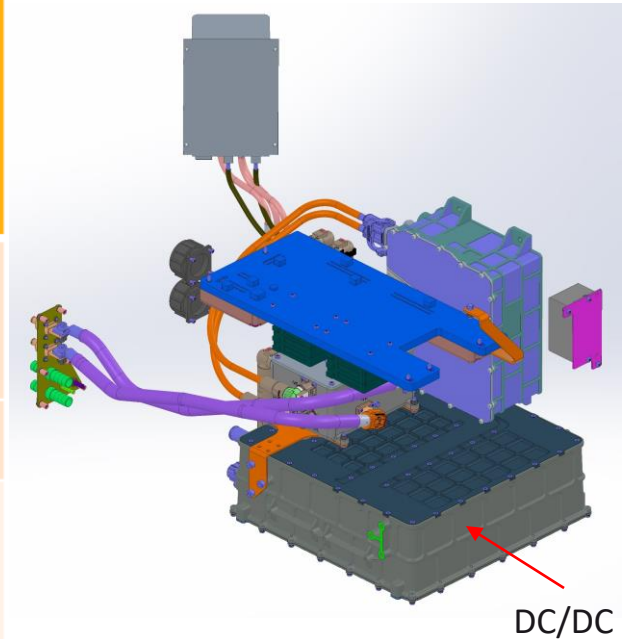
Reduction in the fuel cell system complexity results in **weight, volume and cost saving** at the useable integration level.



High voltage PCBFC stack – impact on DC/DC sizing and specification



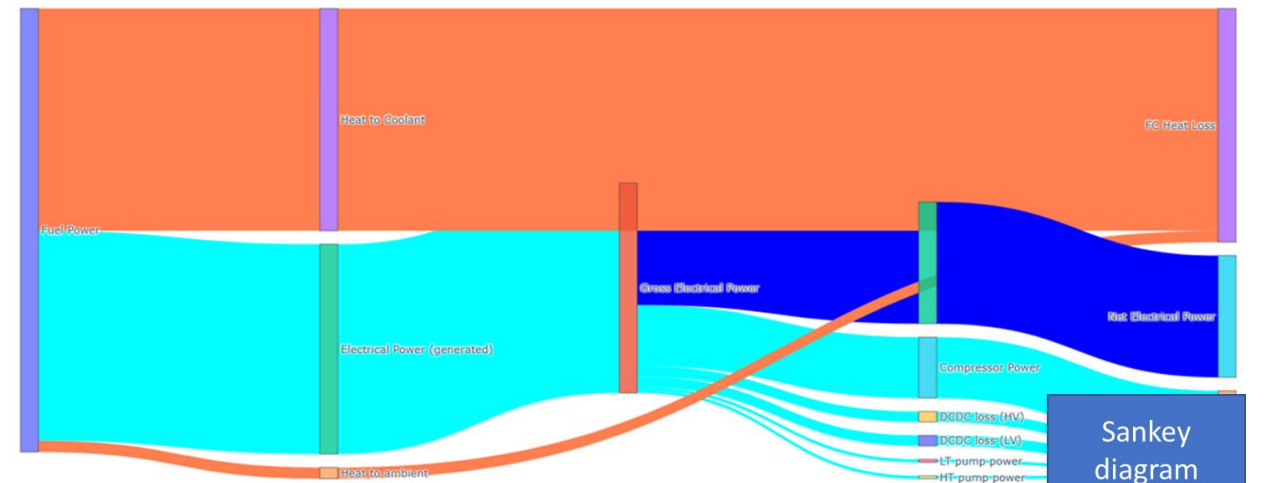
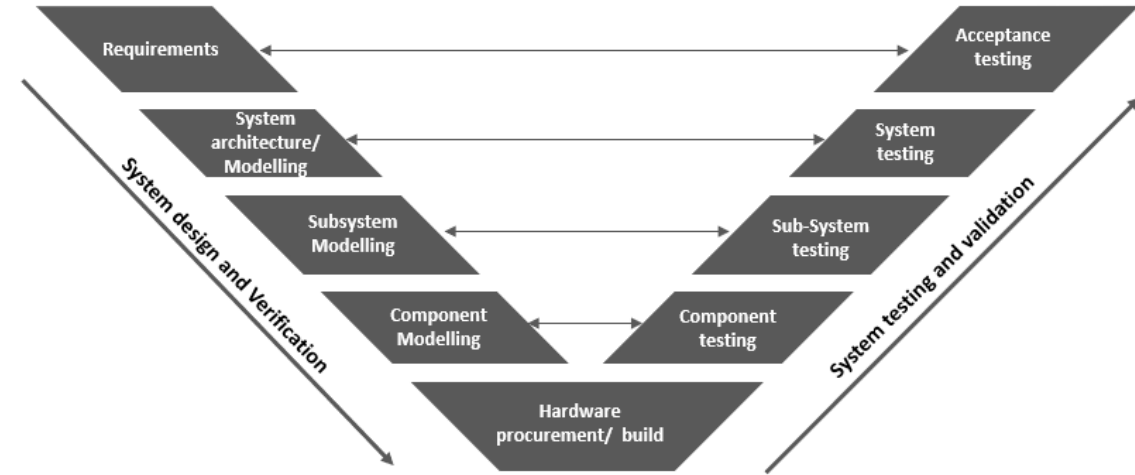
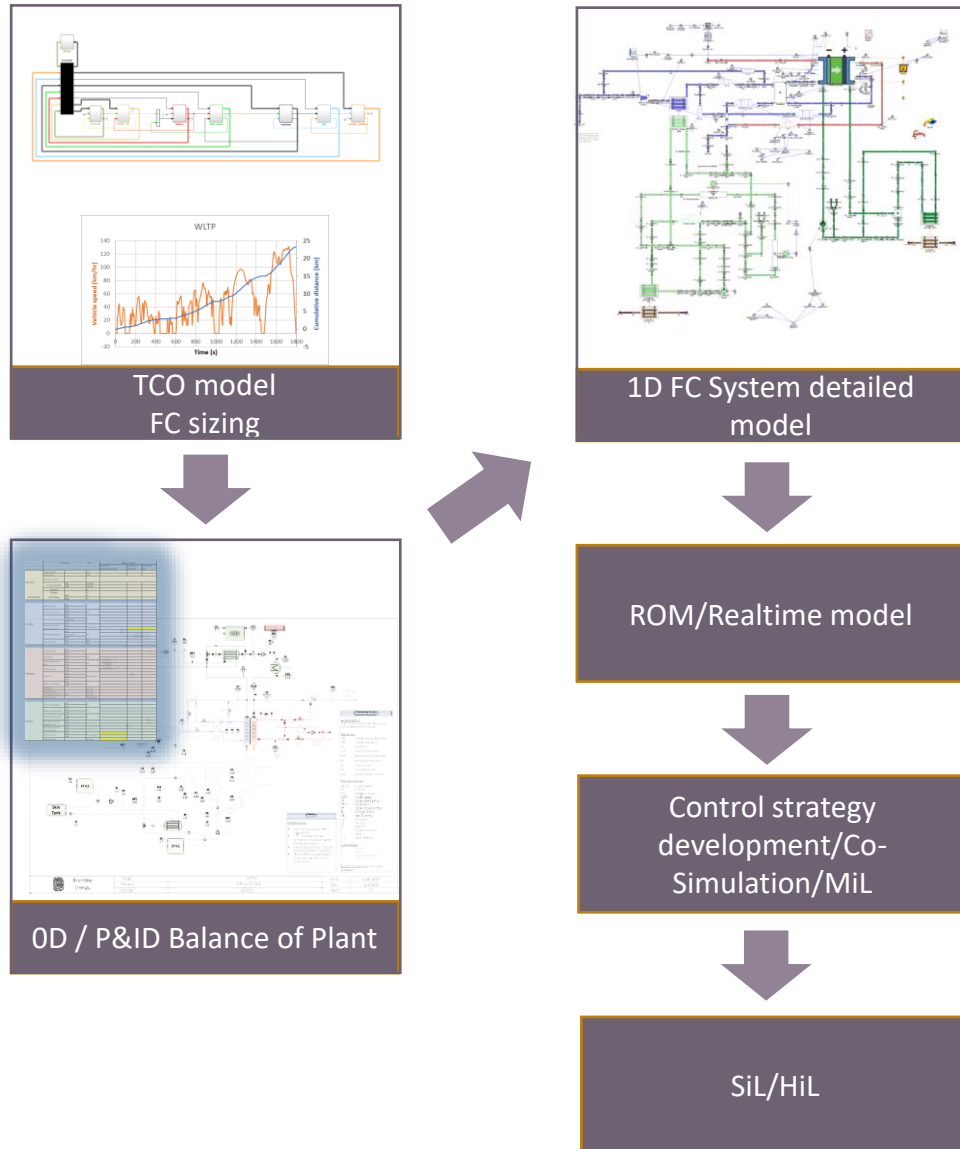
FC electrical system



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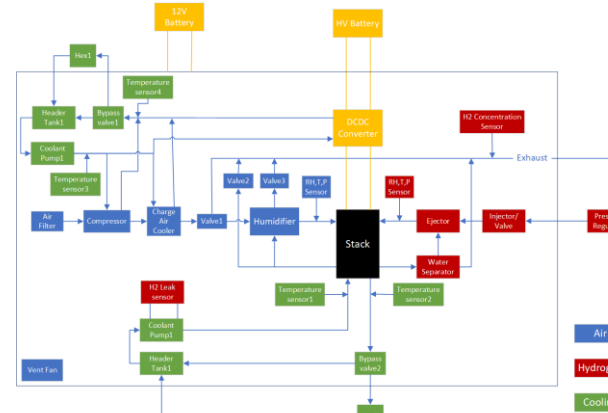
Comparison vs baseline DC/DC for FC 200-500V Vehicle battery @800V	100 kW FC @ < 800V (boost) – impact on DC/DC	100 kW FC @ 1000V (buck) – impact on DC/DC
Weight	Please contact Bramble Energy for details	
Packaging		
Cost		
Impact		
Other impacts		

Model Based Development approach



Fuel Cell system layout – Balance of Plant development

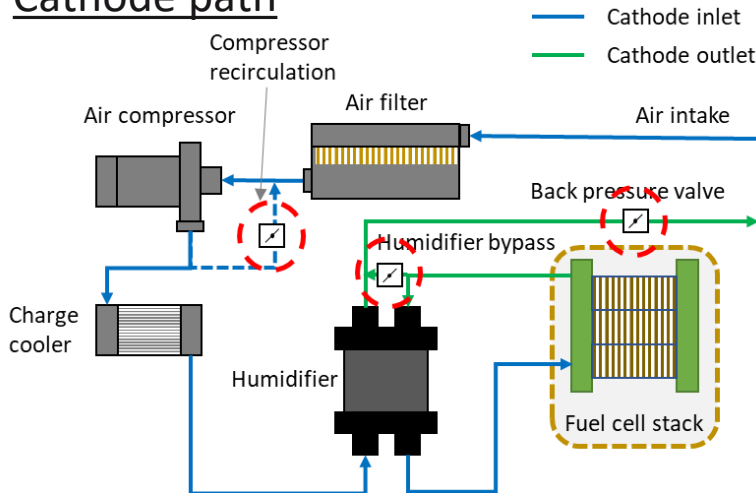
- *BOP systems developed through System Engineering approach* (FMEA, FTA, DVP) with supply chain development
 - Functional requirements: control in Pressure / Temperature / Mass flowrate / Relative Humidity / Stoichiometry
 - Pressure balance between anode / cathode
 - Hydrogen passive recirculation with ejector
 - No deionizer
- *PDU / Electrical Architecture / Control SW*



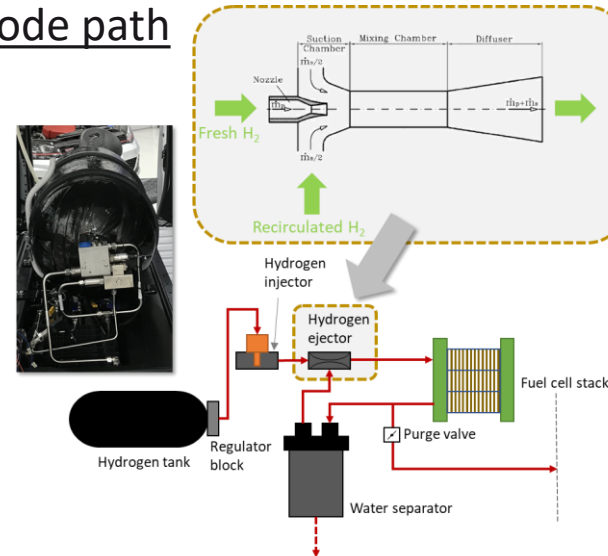
System	
HyTime	
Sub-system	
Air Path	AP
Electronics	EL
H2 Path	HP
Cooling	CL
Stack	ST
Exhaust	EX
Enclosure	EN
Pipework	PW

Component	
Air filter	AP-1
Compressor	AP-2
Valve 1	AP-3
Valve 2	AP-4
Valve 3	AP-5
Humidifier	AP-6
12V battery	EL-1
11V battery	EL-2
DCDC Converter	EL-3
H2 Leak detector	EL-4
Control HW	EL-5
Cabling	EL-6
Electrical Junction Box	EL-7
Inverter	EL-8
Emergency Stop	EL-9
Pressure regulator	HP-1
Injtor Valve	HP-2
Stack inlet combined sensor	HP-3
Water separator	HP-4
Purge to exhaust valve	HP-5
Ejector	HP-6
H2 Concentration sensor	HP-7
Header tank	CL-1
Stack coolant pump	CL-2
Electronics coolant pump	CL-3
Temperature sensor1 inlet	CL-4
Temperature sensor2 inlet	CL-5
Temperature sensor3 inlet	CL-6
Temperature sensor4 inlet	CL-7
Header tank H2 leak sensor	CL-8
H2/Nitrogen Concentration sensor	EX-1
Mixture junction manifold	EX-2
Cathode Exhaust	EX-3
Anode Exhaust	EX-4
Anode Connections	ST-1
Cathode Connections	ST-2
Coolant Connections	ST-3
Seals	ST-4
Electrical tabs	ST-5
Mounting points	ST-6
Endplates	ST-7

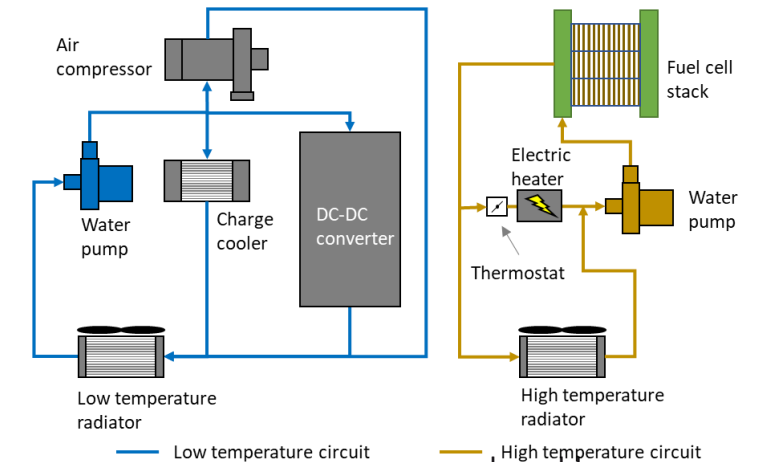
Cathode path



Anode path



Cooling circuits

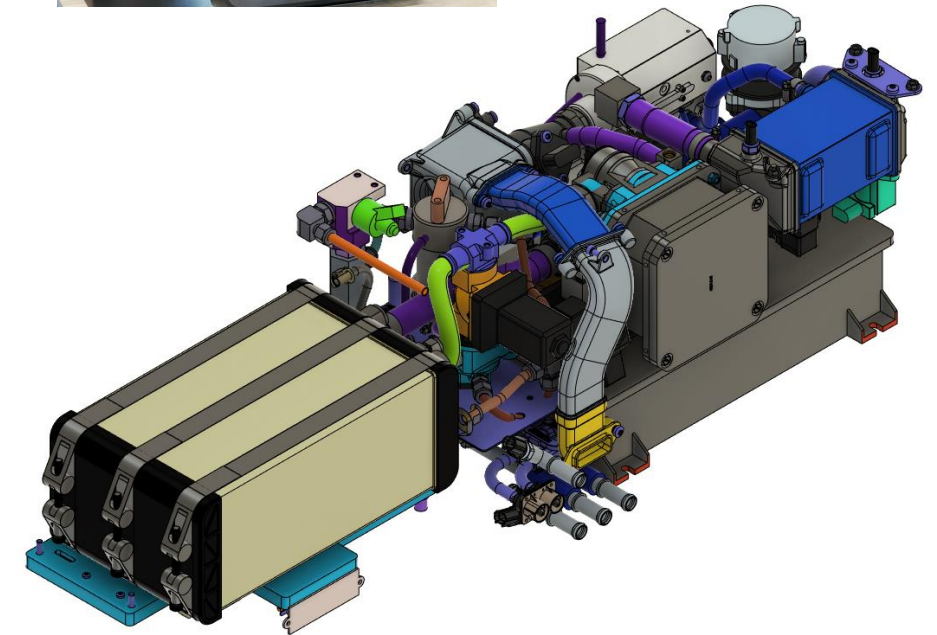
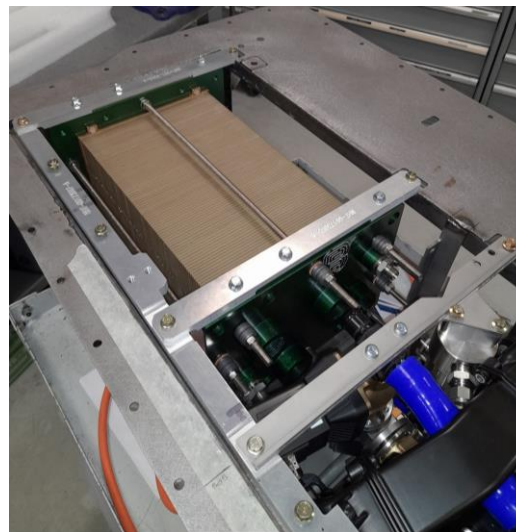


Automotive Application

Low-cost, range-extender

Bramble Energy's liquid-cooled PCBFC™ has been integrated into a Renault Kangoo ZE – thanks for Innovate UK funding.

This demonstrator was developed in collaboration with MAHLE Powertrain to showcase the reduced cost, high performance capability of our high-power density liquid cooled fuel cells.



Marine application

Zero-emission shipping

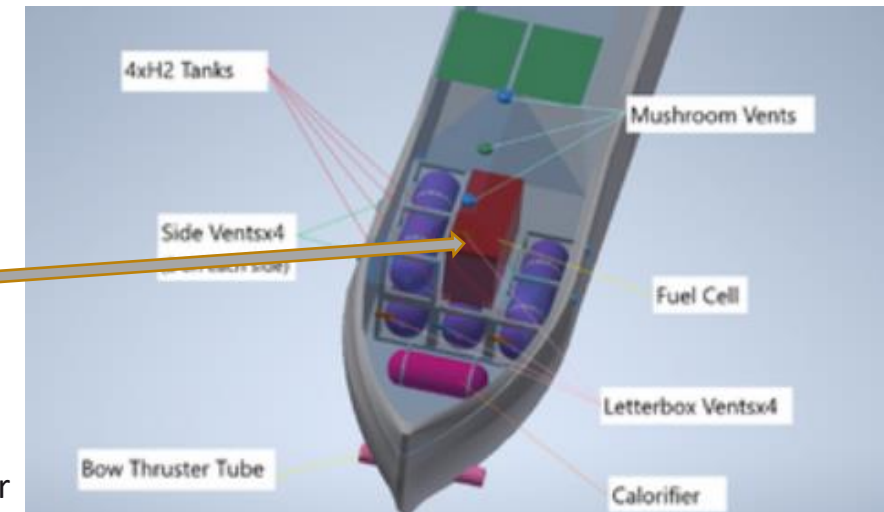
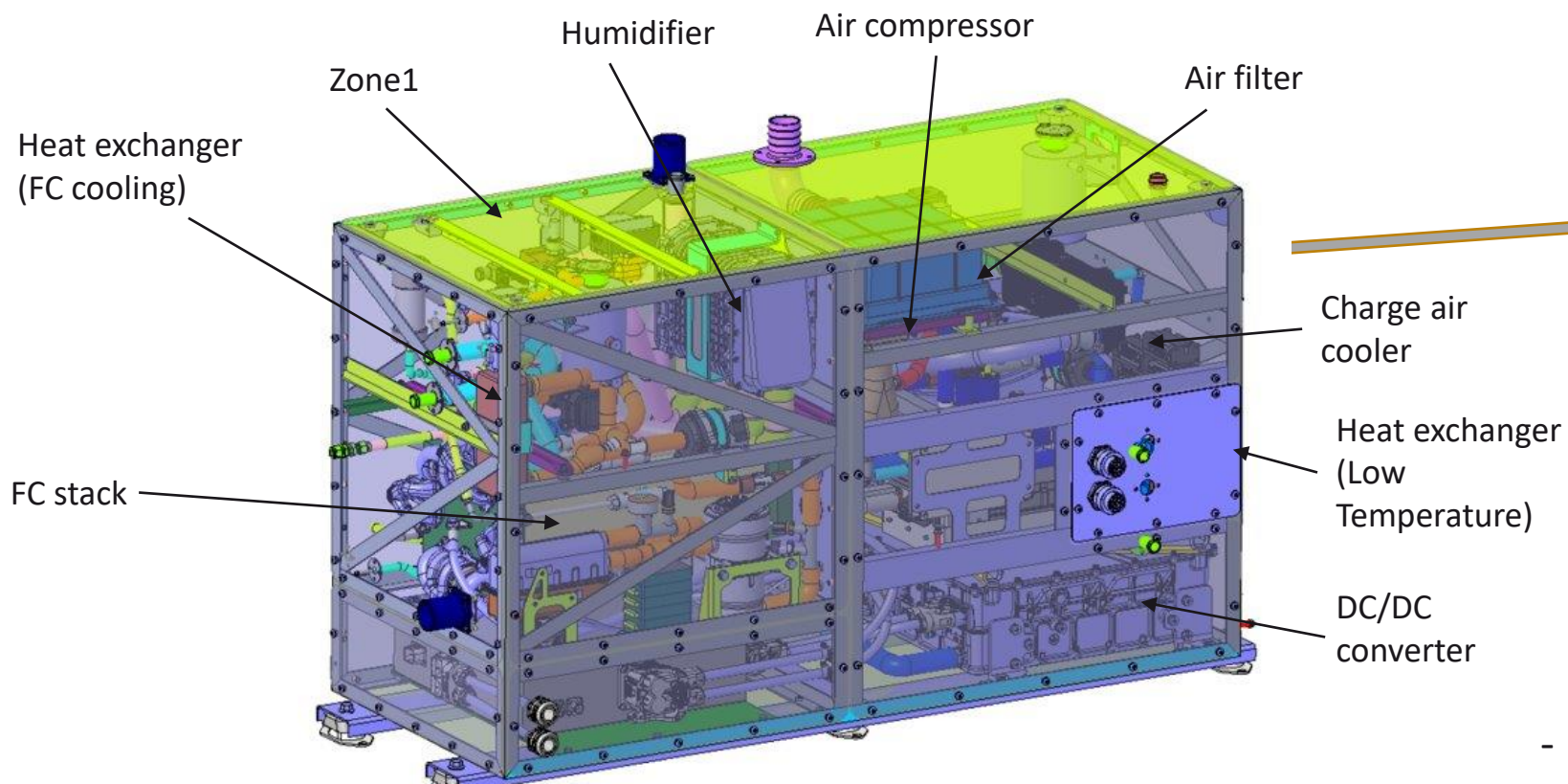
Bramble is targeting 'Approval in Principle' in Q3 2023 for 15-30 kW marinised fuel cell systems, based around the modular, low-cost PCBFC™ technology these systems are being demonstrated in an uncrewed surface vessel, an inland waterway recreational boat throughout 2022/2023.

The modular PCBFC™ approach provides a cost advantage and flexibility to integrate the fuel cells within marine vessels.



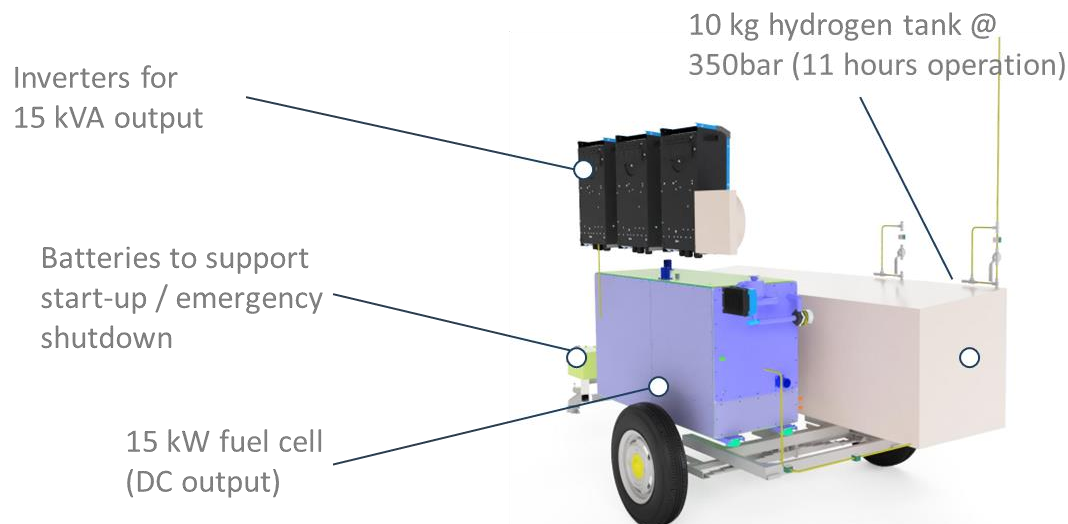
MARINE – 15kW Fuel Cell System to be installed on Barrus canal boat

- 2nd Fuel Cell System (15kW) developed for marine / maritime applications having design features to fulfill Lloyd's Register requirement
 - targeting **Approval in Principle** with 3rd generation developed in CMDC2 with Sea-Kit on 30kW
- 15kW FC system adapted for genset application on a trailer (context of Red Diesel Replacement phase 1 funding project)



Genset – 15kW

- BEIS-funded red diesel replacement project
- 15 kW prototype fuel cell demonstrator recharging 200 kWh electric crawler crane on H2 construction site, end Q2 2023
- Key stats
 - 10kg hydrogen tank at 350bar
 - 11hrs operation delivering 165 kWh charge
- Prototype unit designed with H2 storage for one day's operation
- Development with Fuel Cell Systems Ltd



The Bramble Energy Advantage

The PCB industry uses a digitally tooled manufacturing process. This, unlike traditional electrochemical device manufacturers, Bramble Energy's PCB-X™ devices do not require analogue tooling in its construction. This allows for a **rapidly adaptable form-factor, with minimal turn-around time and cost.**

No investment in Giga-factory required.



Low cost



Rapid



Customisable



High specific
power

The PCBFC™ stack is not confined to monolithic blocks. The laminated module construction brings an advantage in **form factor flexibility**, leading to **high specific power** fuel cell products of **any shape and size** that can be integrated into any vehicle without costing the earth.

Thanks for your attention & questions

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