



Intelligent Energy

PEM Fuel Cell Technology & Products

Dr Simon Foster
Head of Fuel Cell Research & Development

Powering the hydrogen future®

Hydrogen fuel cell manufacturer

Products from 800W to 300kW

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



23 years' experience

160 employees

Over 600 patents

12 modular products



Based in the UK with
representation in
US, Japan, South Korea and
China.



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

What is a fuel cell?



Fuel cells **generate electricity** through an environmentally friendly **electrochemical reaction**.

A **zero-emissions** solution.

Produces continuous power when hydrogen and air are supplied.

No combustion is involved.



Fuel cell stack

+



Hydrogen

+



Air

=



Electricity

+

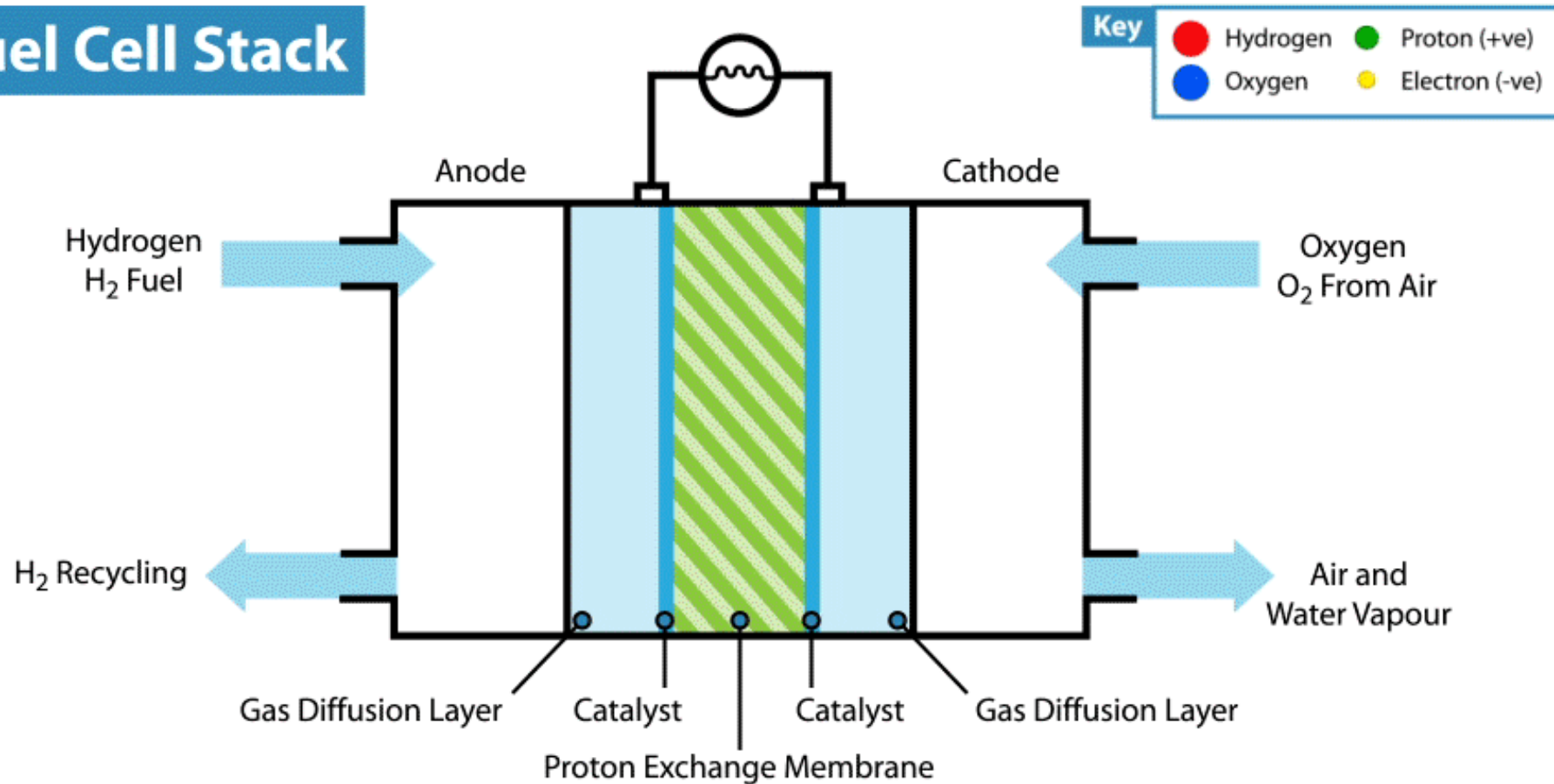


Pure water

How does a PEM fuel cell work...

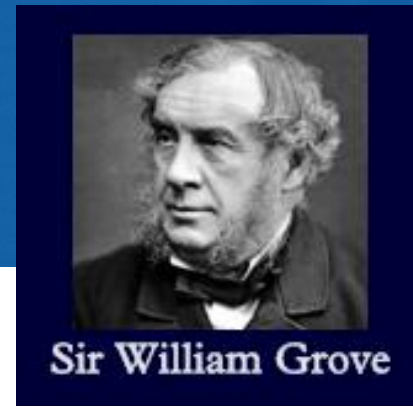


Fuel Cell Stack



A brief history of fuel cell technology...

- First reported in 1839 by Sir William Grove
- Early polymer FC powered Gemini missions
- Alkaline FC used in Apollo and early shuttle

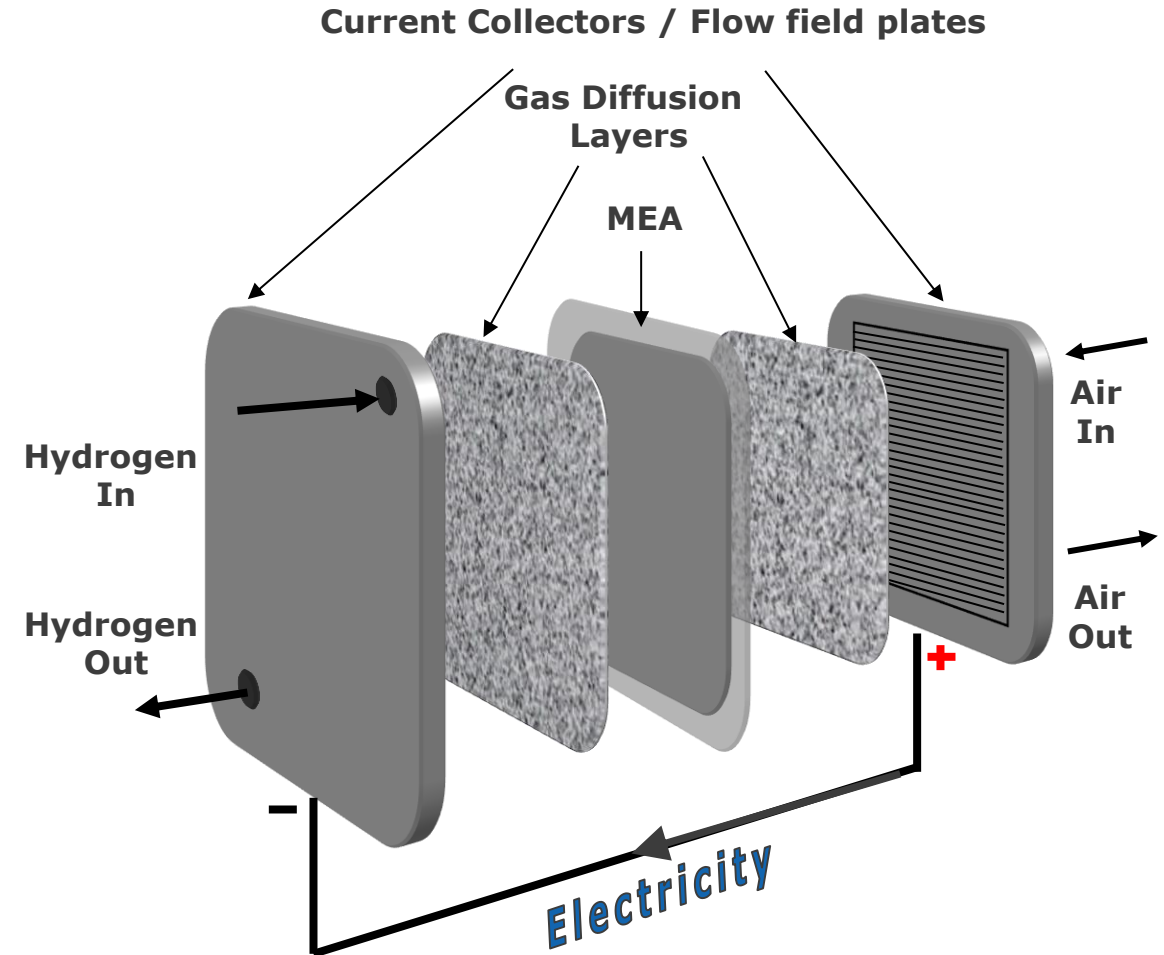




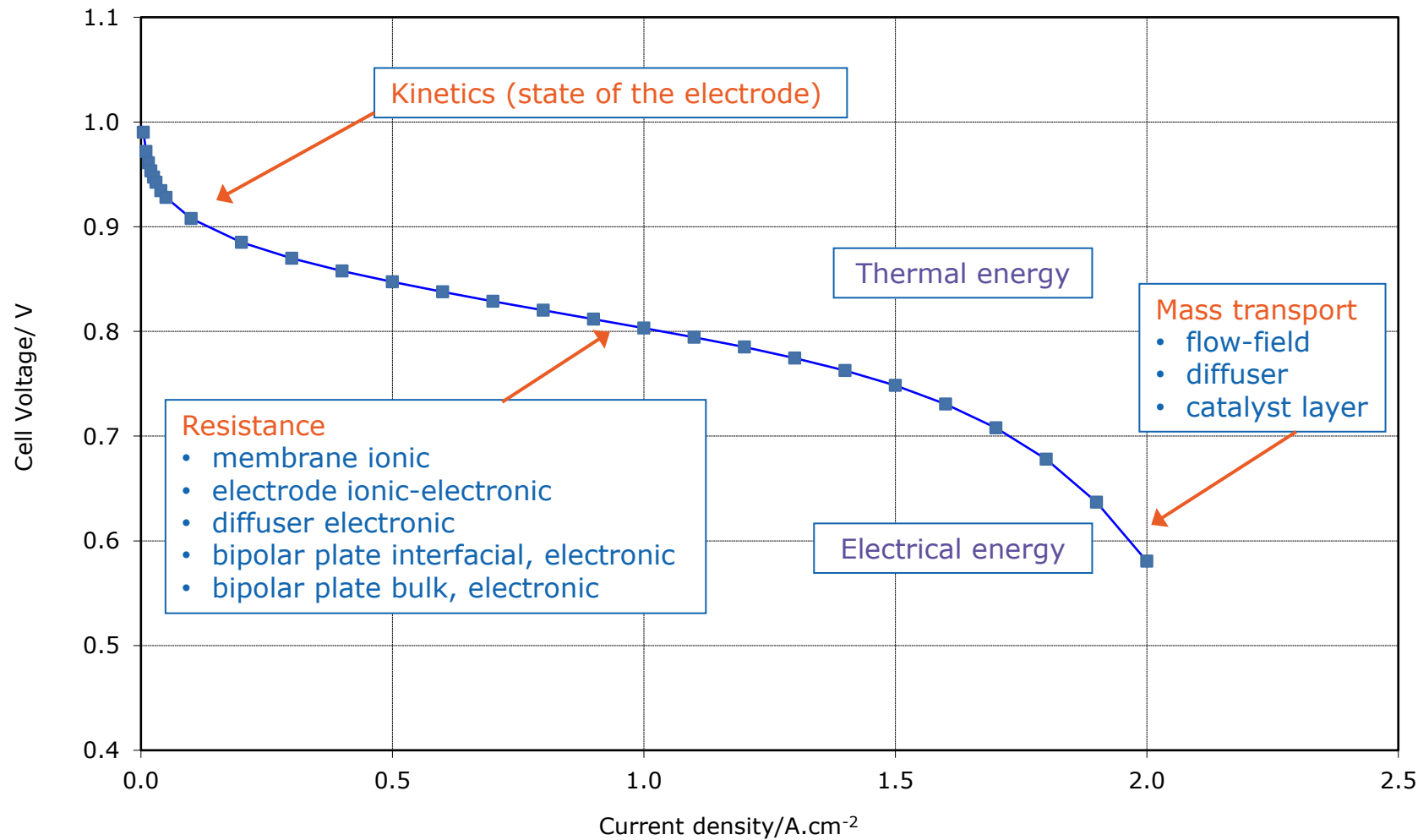
PEM fuel cell – the key components...

Starting from middle

- MEA/PEM
 - Proton (H^+) permeable membrane
 - Permeable electrodes with catalyst
- Diffuser/GDL x 2
- Plates with flow fields x 2
- +ve 'air' terminal is the cathode
- -ve 'hydrogen' terminal is the anode
- Seals to contain the H_2 and air not shown
- Clamping not shown



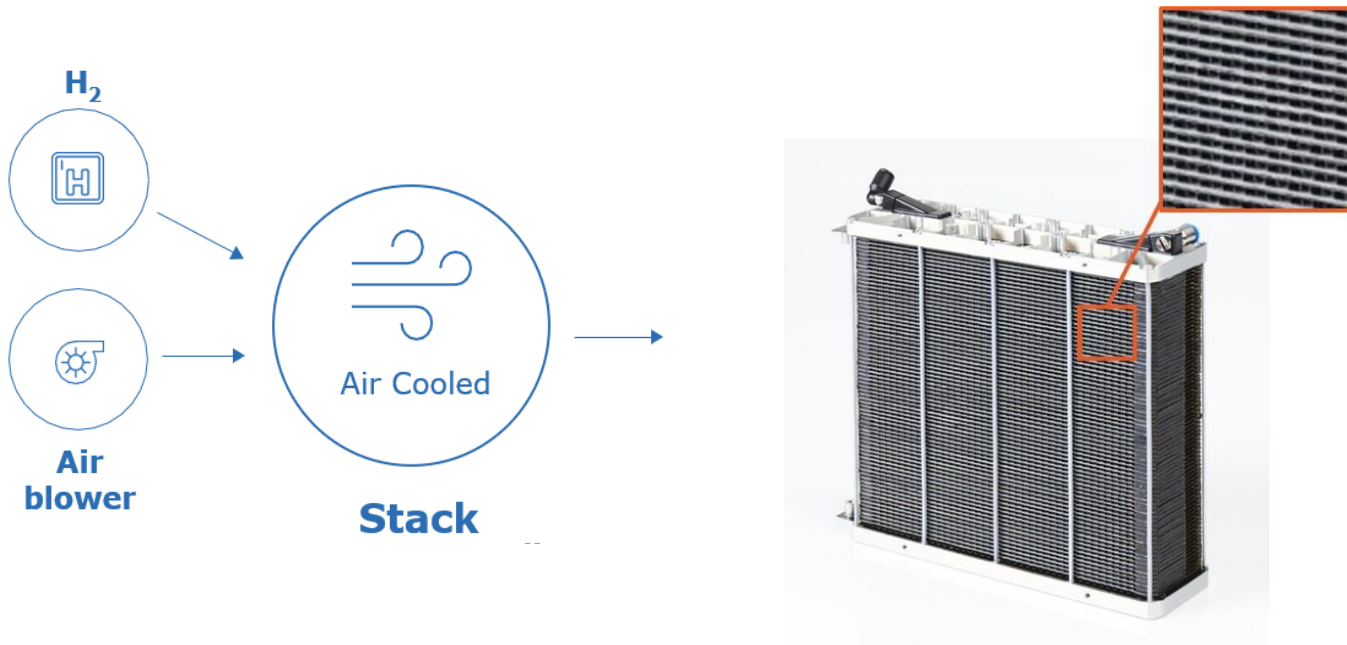
A typical fuel cell polarisation curve



What is air cooled PEM FC technology...



FCs that are cooled by a fan that also provides the necessary reaction air



Benefits	IE
High power density	✓
Simple components	✓
Lower cost at volume	✓
High reliability	✓
Stable efficiency and performance	✓
Lightweighted for UAV market	✓



Liquid and Evaporatively-Cooled PEM FC technology...

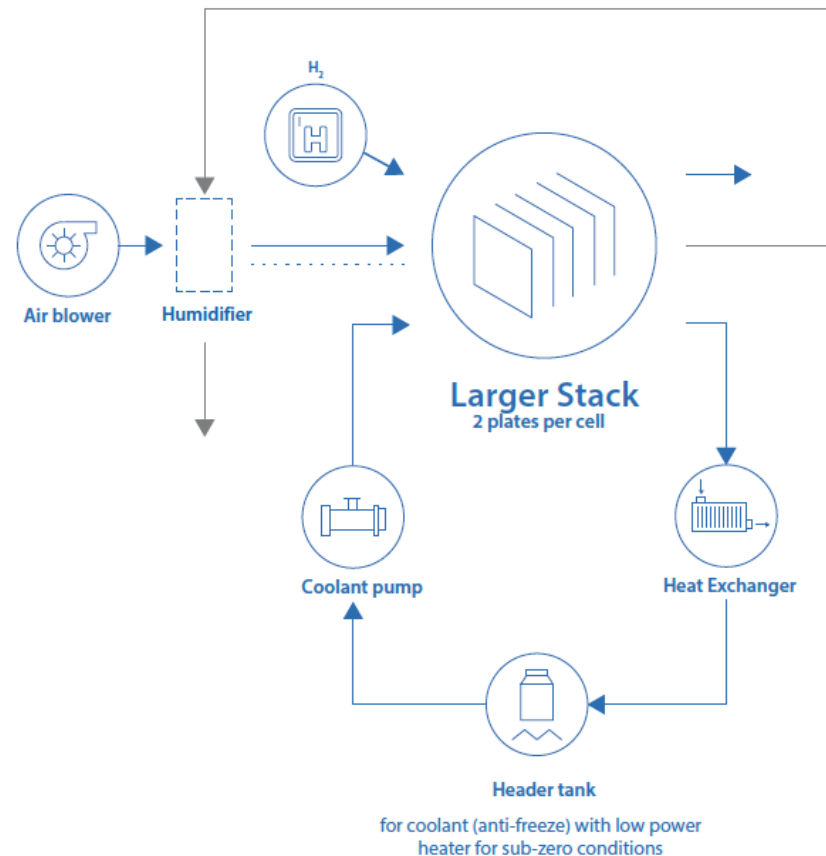


Benefits	IE
High power density	✓
Lower component count	✓
Lower cost at volume	✓
High reliability	✓
Stable efficiency and performance	✓

Components	LC	IE
Stack cooling plate	✓	-
Humidifier	✓	-
Heat exchanger	✓	Smaller
Coolant pump	✓	✓
Air compressor	✓	✓
Coolant storage	✓	✓

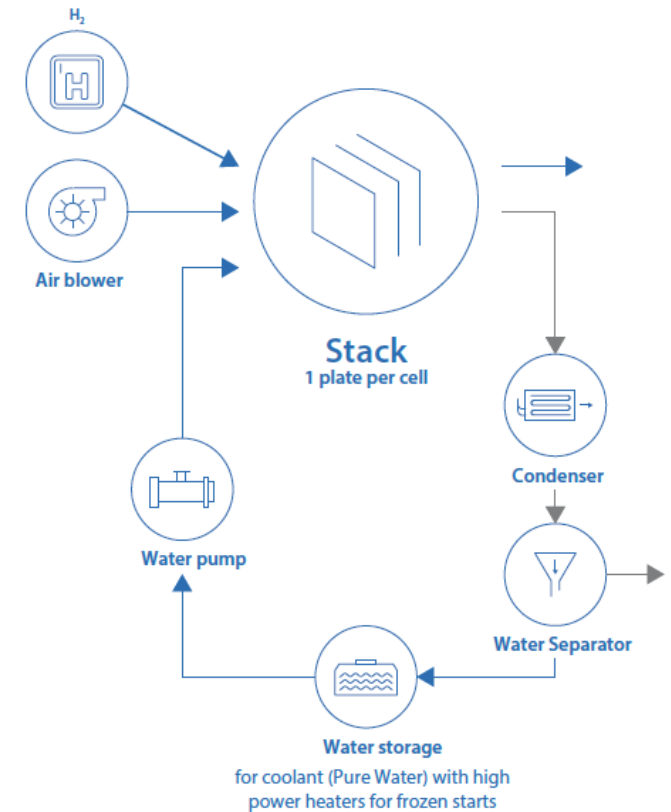
Liquid Cooled Technology

Separated coolant and oxidant channels



Evaporatively Cooled Technology

Combined coolant and oxidant channels



Zero-emission power from 800W to 1MW



IE-SOAR

800W – 24kW

Lightweight fuel cell modules for
drones and VTOL applications



IE-POWER

1kW – 32kW

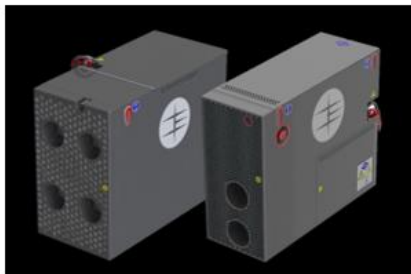
Clean power for construction,
standby power and telecoms



IE-LIFT

1kW – 60kW

Battery box replacement for
material handling equipment



IE-DRIVE

100kW – 300kW

Fuel cells for buses, trucks, cars,
rail and marine



IE-FLIGHT

100kW – multi-MW

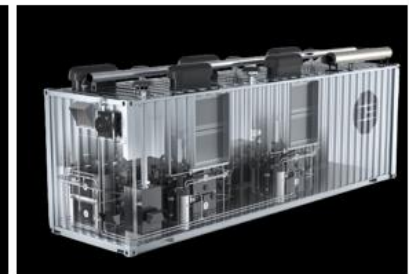
Zero-emission flight for eVTOL,
small aircraft and large aircraft



IE-GRID

200kW – 1MW

Fuel cell distributed power
solutions



IE-SOAR:

800W – 24kW for drone and VTOL applications

- 3 to 5 times the flight time over batteries
- 2–3-minute refueling - operational efficiency
- Enable previously challenging applications
- Modular – combine systems in parallel for 1.2kW, 2.4kW and 4.8kW outputs
- Direct battery replacement – Automatically follows load demand just like a battery
- Range of integrations – VTOL, fixed wing, rotary wing
- Certified – to CE and FCC standards

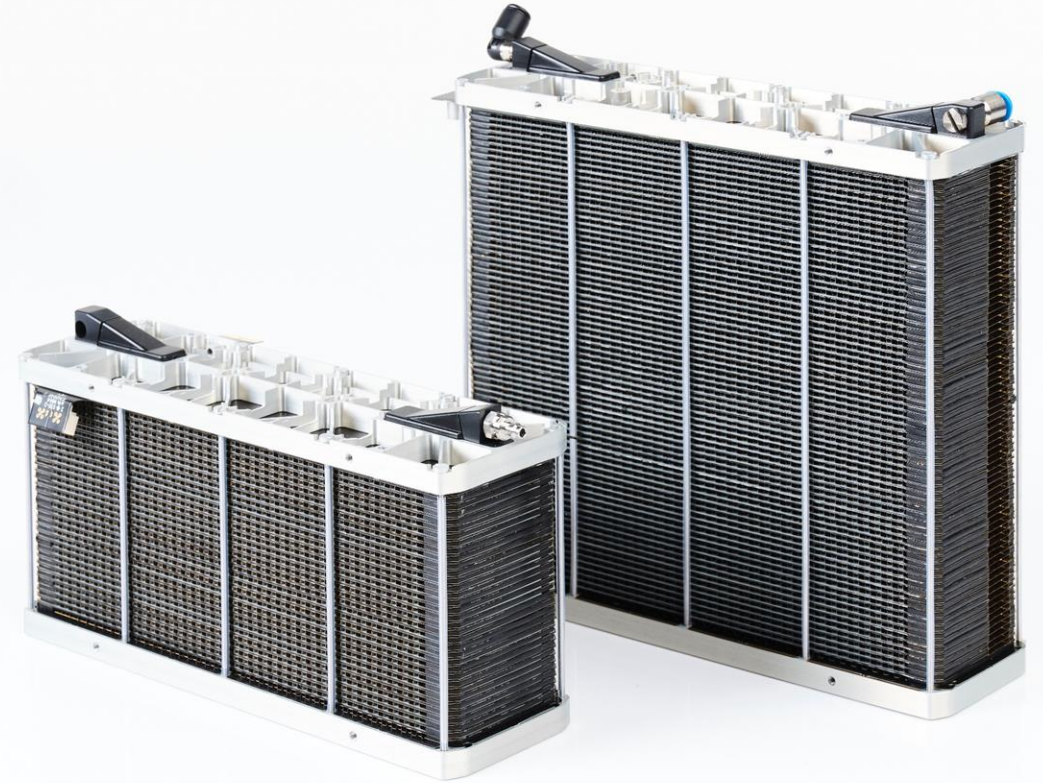


Lightweight technology required



Miniaturisation and mass out

- Stack integrated valves
- Lightweight current collectors
- Low mass endplates – lighter alloys and removal of all non-structural material
- Lower mass cell recipe, thinner lighter materials

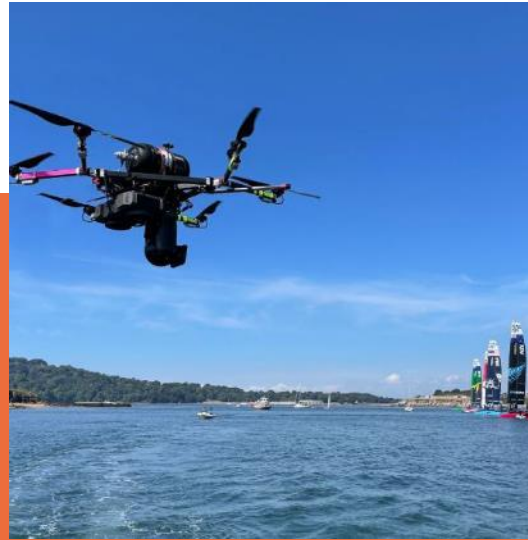


Operational Highlights

IE-SOAR product in use in real world applications



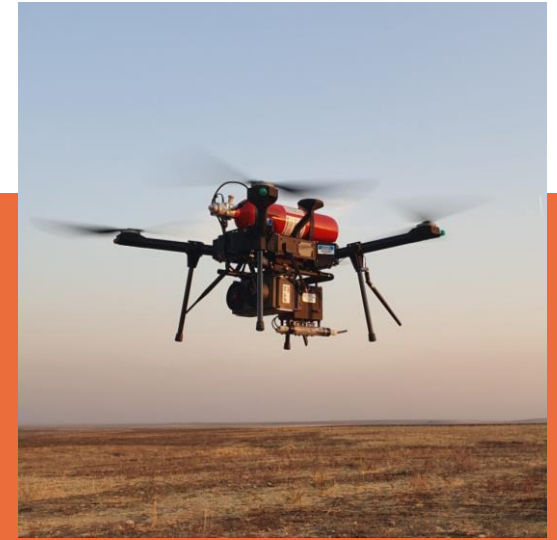
**Pipeline inspection
with Shell**



**Broadcasting the Sail
Grand Prix**



Military Surveillance



Oil Field Inspection

IE-POWER:

1kW – 32kW for standby power, telecoms and construction

- ✓ Small, light, power dense hydrogen fuel cells
- ✓ Modular, scalable and easy to integrate
- ✓ Unique patented airflow management
- ✓ Quiet operation
- ✓ Wide environmental envelope
- ✓ Robust against high shock and vibration incidence



IE-POWER 1



IE-POWER 4

Operational Highlights

Zero emission hydrogen fuel cell solutions to meet your net zero targets



Zero emission disaster response, emergency power solution in the USA



Stationary power for welfare cabins on HS2 sites



Portable power solution used during construction work at Shibuya Crossing, Tokyo



Power in off-grid locations in the Alps with Powidian

IE-LIFT:

1kW – 60kW for material handling equipment

- Complete battery replacement – 24V / 36V / 48V
- Simple retrofit using existing FLT connections
- Rapid refuelling improves fleet availability
- Easily scalable with site / fleet expansion
- Improved TCO for intensive operations



Operational Highlights

Rapid refuelling, improved availability, lower Total Cost of Ownership



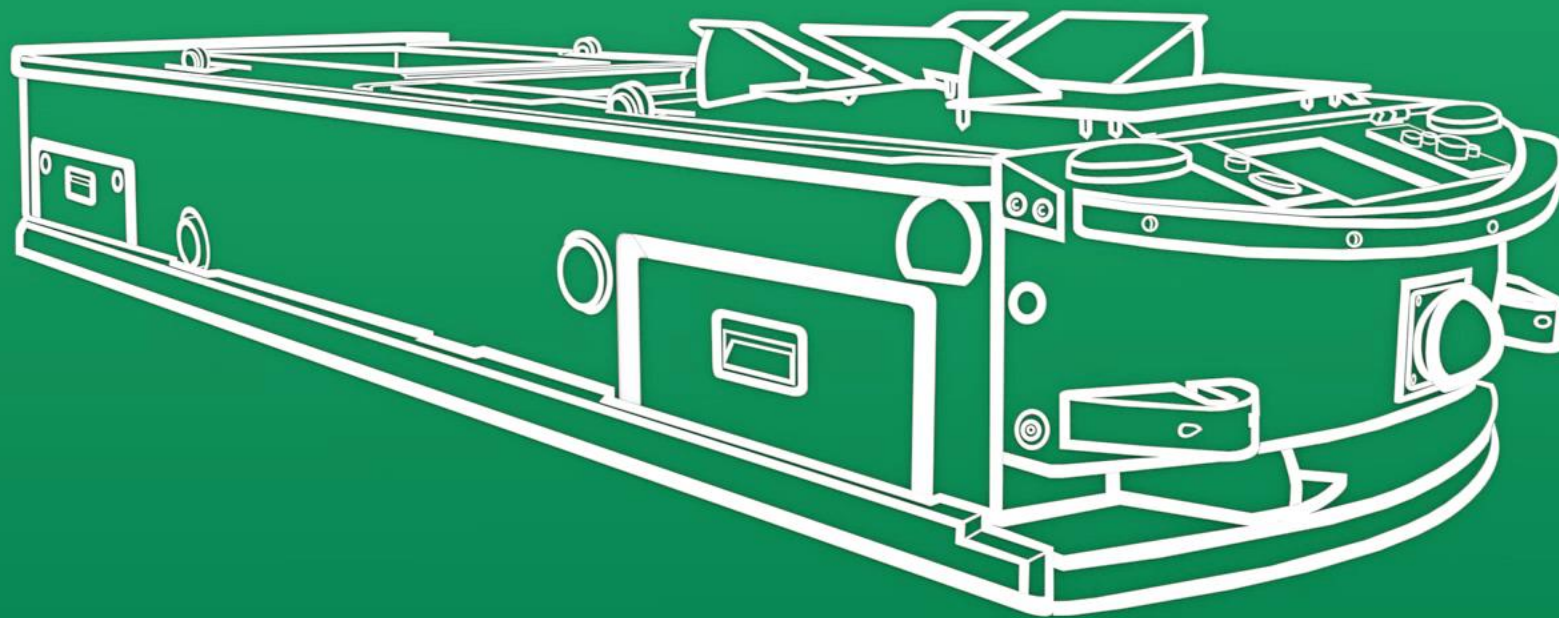
**Fuel cell powered
Automated Guided
Vehicles at BMW Plant**



**World's first hydrogen-
electric powered access
platforms with Niftylift**



**Fuel cell battery box
replacement for MHE
solutions**



IE-DRIVE:

100kW – 300kW for automotive applications

- ✓ High power density
- ✓ Compact and easy to integrate
- ✓ Patented cooling technology
- ✓ Scalable and modular
- ✓ Long life span
- ✓ Range and re-fuelling experience similar to ICE



Case studies

High power, lightweight, modular fuel cells for automotive and stationary use



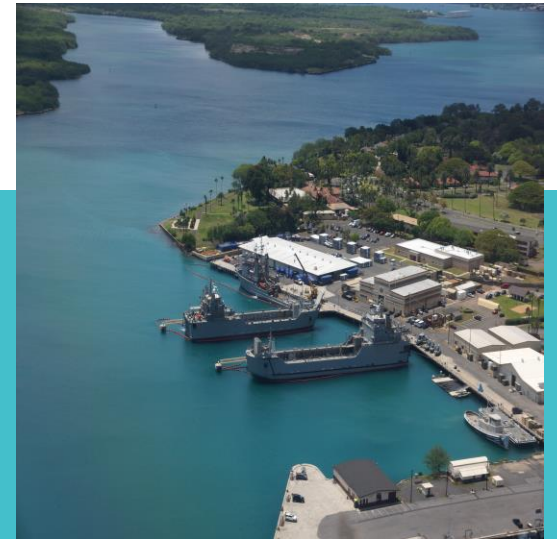
**Fuel cell powered
passenger vehicles with
Changan UK**



**44 tonne HGV developed
with MIRA and Viritech**



**Fuel cell powered buses
with TYCE, Taiwan**

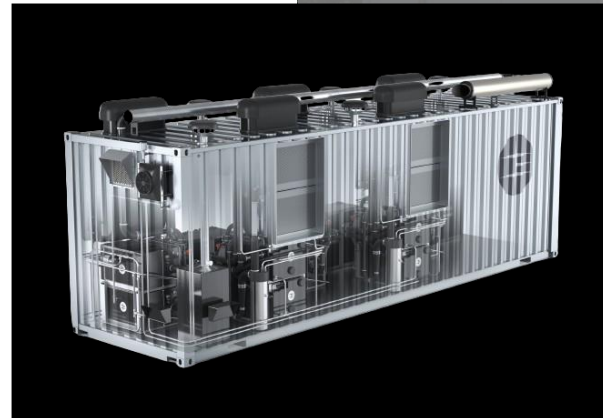


**600kW microgrid at
Hickam Air Force Base in
Honolulu, Hawaii**

IE-GRID:

100kW to multi-megawatt grid applications

- ✓ Leading power density
- ✓ Scalable to multi-megawatt
- ✓ Various configurations
- ✓ Higher-grade heat is achievable
- ✓ CHP operation – usable heat at 110C
- ✓ Zero-emission



Fuel cells for scaled stationary power

Applications

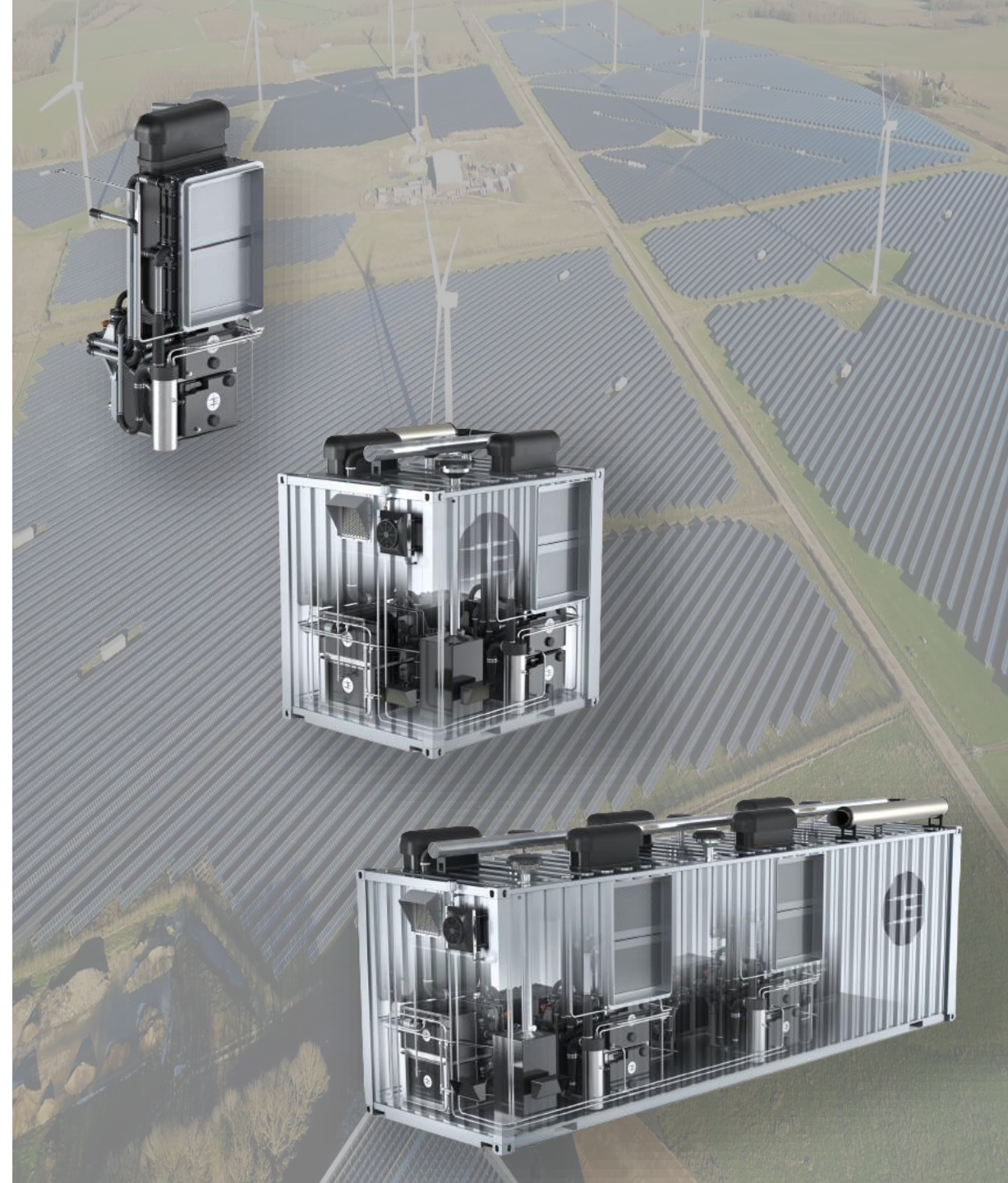
- Micro-grids
- Off-grid reliable power supply

Technology advantages

- Scalable from 100kW to multi-megawatt
- Zero emissions
- CHP operation – usable heat at 110C
- Fast power changes – 1MW station can turn on in seconds

Configuration flexibility

- Higher-grade heat is achievable
- Independence of ambient conditions



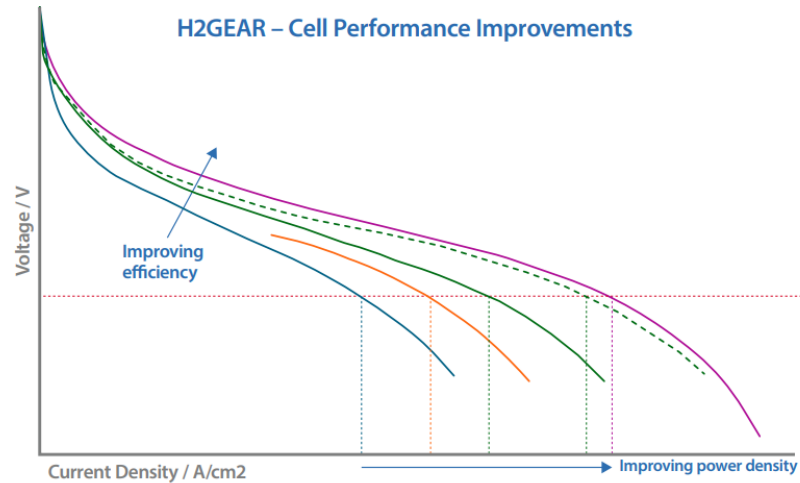
IE-FLIGHT:

100kW – 1MW for aerospace applications

- ✓ Offer zero-emission energy solutions
- ✓ High power density
- ✓ Compact and easy to integrate
- ✓ Unique patented airflow management
- ✓ Scalable and modular
- ✓ Long life span

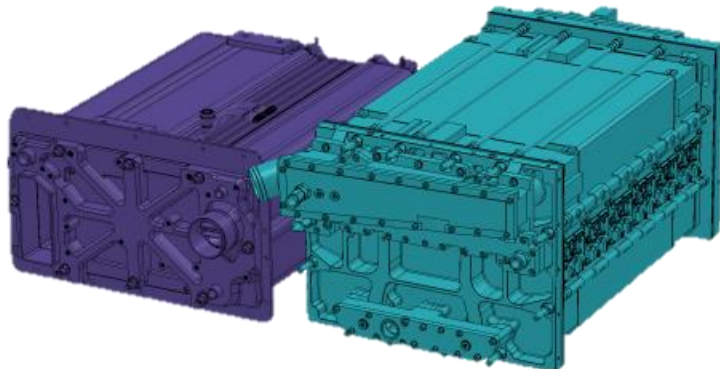


Current IE-FLIGHT development activity under H2GEAR Programme



Aero FC stack

Auto FC stack



IE-FLIGHT technology

Overcoming fuel cell challenges in aero



Fuel cell propulsion units being flight tested today have large thermal management systems which are heavy and increase aerodynamic drag



- Low temperature high-power PEM fuel cells operate at $\sim 80^{\circ}\text{C}$.
- Lower ΔT means larger air intake, bigger and heavier heat exchangers, and increased drag on the aircraft.



IE-FLIGHT stack module



IE-FLIGHT F300

Fuel Cell Research & Development needs



UAVs



Materials Handling



Stationary Power



Automotive



Aerospace



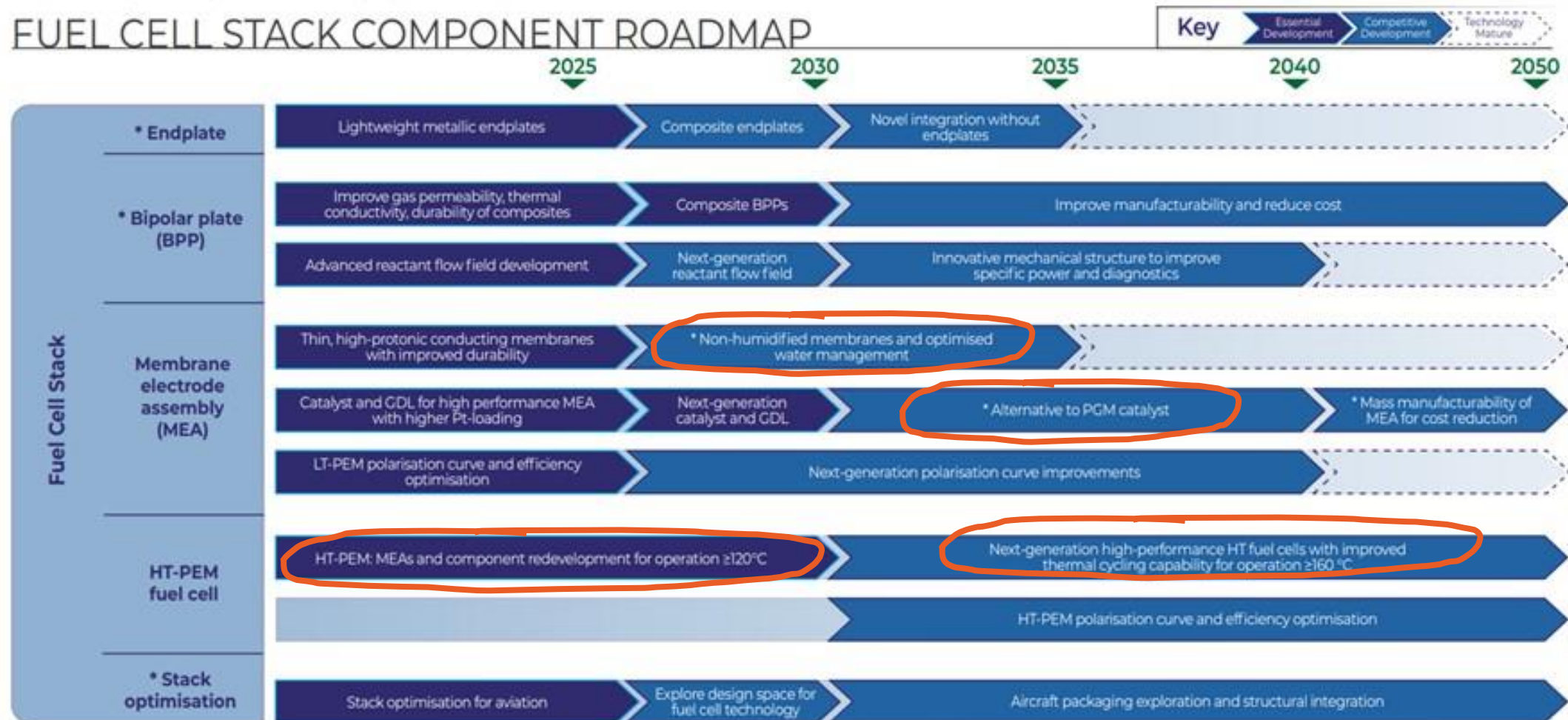
FC stack R&D needs for aero applications



Aerospace Technology Institute - FlyZero - Fuel Cells - Roadmap Report

FZO-PPN-COM-0033

FUEL CELL STACK COMPONENT ROADMAP



FC stack R&D needs for motive applications



Roadmap 2020
Fuel Cell

Technology Roadmap

Technology indicators for
2020-2035 can be seen on page 1



This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.



Light bar:
SOFC Specific
technologies for mass
market application



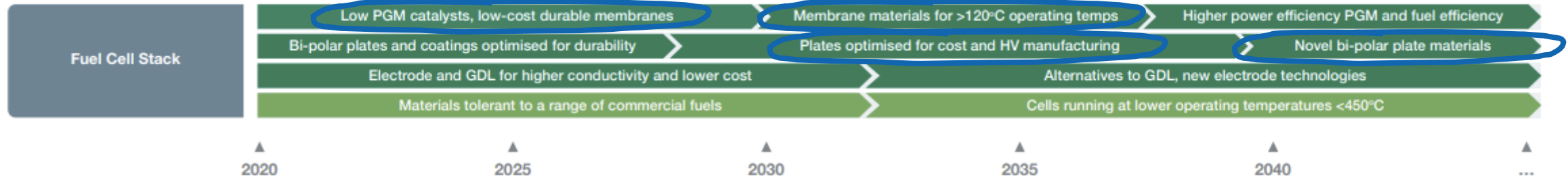
Dark bar:
Common or PEM – technology is in a
mass market application. Significant
innovation is expected in this time frame



Transition:
Transitions do not mean a
phase out from market but
a change of R&D emphasis



Dotted line bar:
Market Mature – technology has reached
maturity. Likely to remain in mass market
until it fades out where it's superseded



FC system R&D needs for motive applications

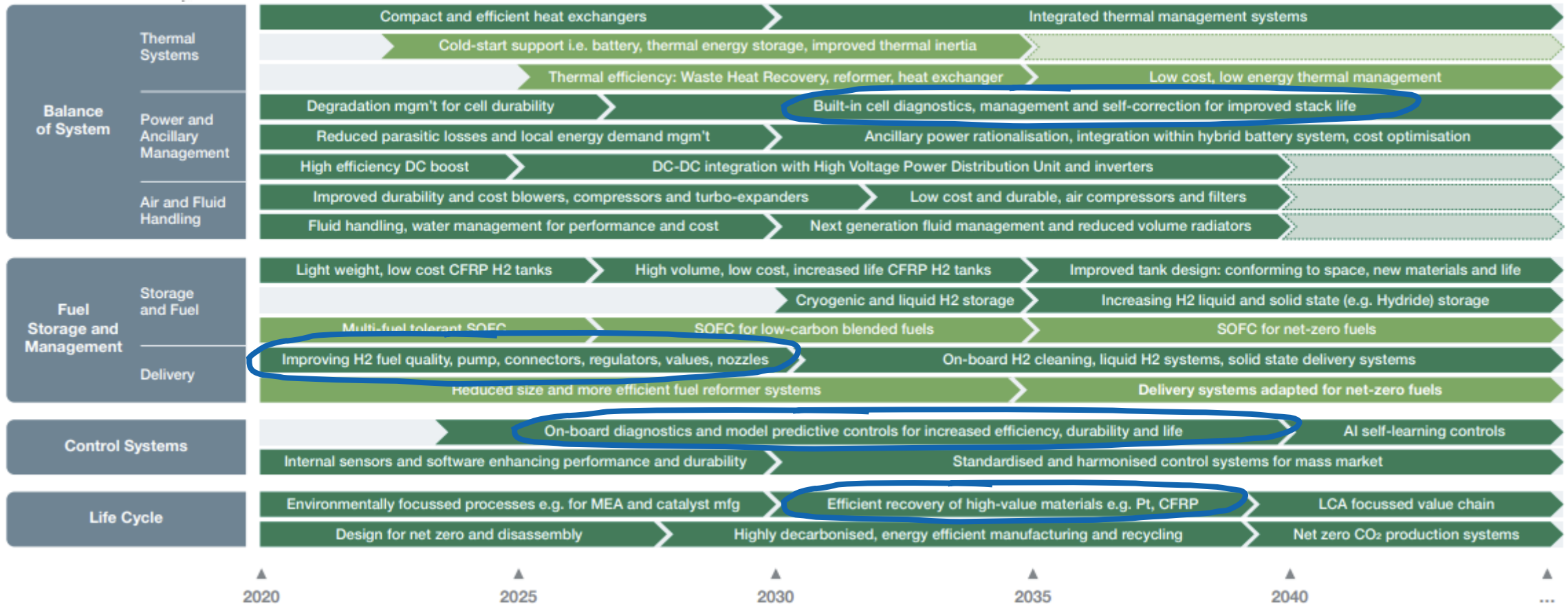


Roadmap 2020

Fuel Cell

Technology Roadmap

Technology indicators for
2020-2035 can be seen on page 1



https://www.apcuk.co.uk/wp-content/uploads/2021/09/https___www.apcuk_.co_.uk_app_uploads_2020_11_Technology-Roadmap-Fuel-Cell.pdf

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Powering the hydrogen future® with our outstanding fuel cells and service.



- The End
- Thankyou!

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