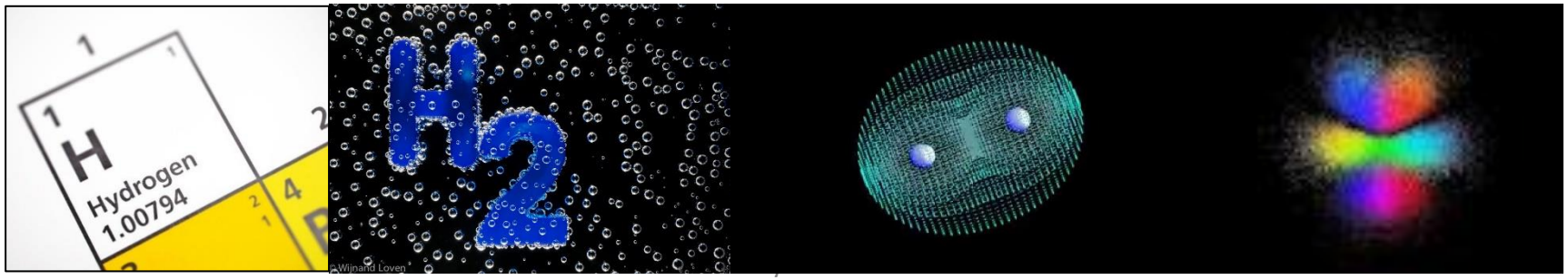
FUEL CELL SYSTEMS®

Introduction to Hydrogen and Fuel Cells

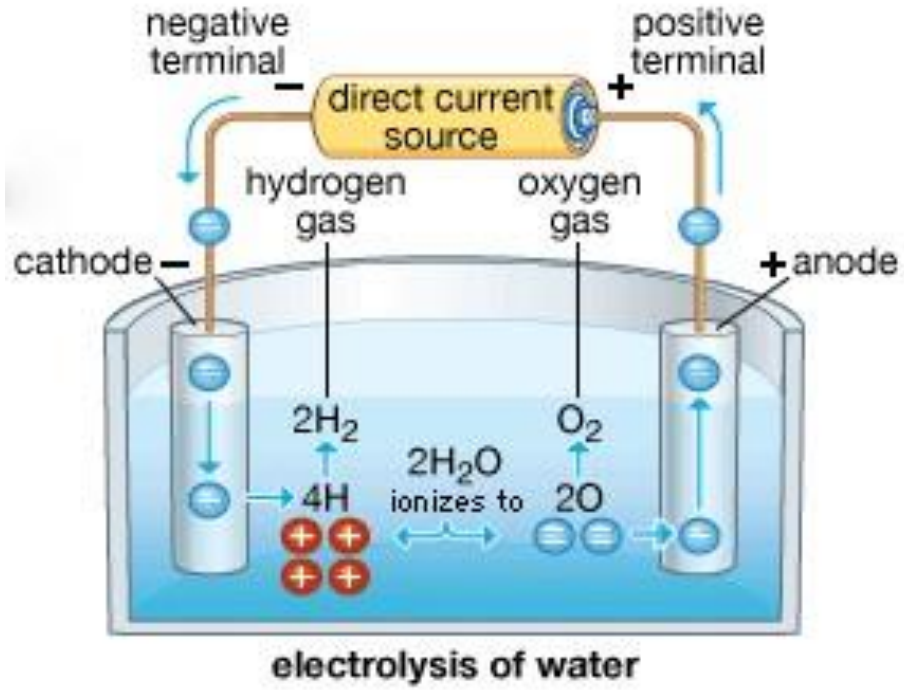
Hydrogen

- Hydrogen makes up about 75% of the mass of the universe. It is found in the sun and most stars.
- Hydrogen is the simplest and lightest element on the periodic table.
- Hydrogen gas is almost always bonded to itself or something else. That is why hydrogen gas is represented as H_2.
- Hydrogen is odourless, colourless, tasteless, non toxic and non-poisonous.
- Hydrogen is highly flammable but will not ignite unless an oxidizer (air) and ignition source are present.
- Hydrogen has been safely produced, stored, transported, and used in large amounts in industry by following standard practices that have been established in the past 50 years.

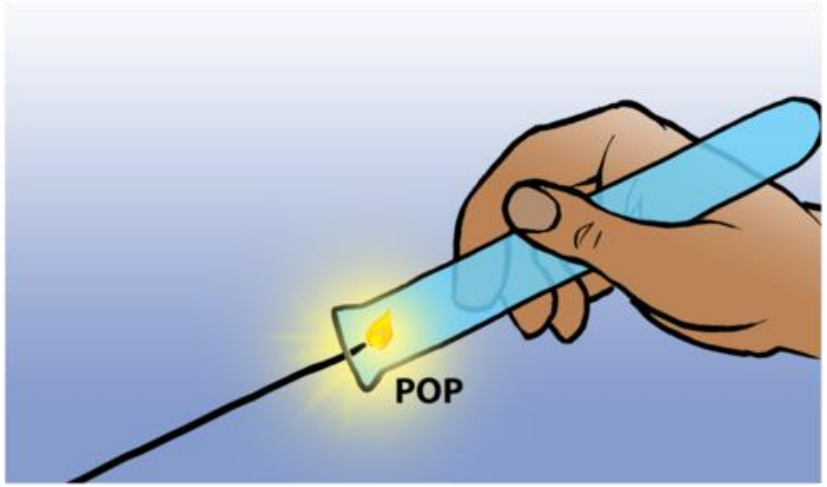


Hydrogen

You are very likely to have handled hydrogen already in school experiments.



electrolysis of water



Hydrogen

Most static hydrogen refuelling stations (HRS) are essentially a large version of the water electrolysis that you may have done at school.
They use electricity produced locally by onsite/nearby renewables to spilt water.

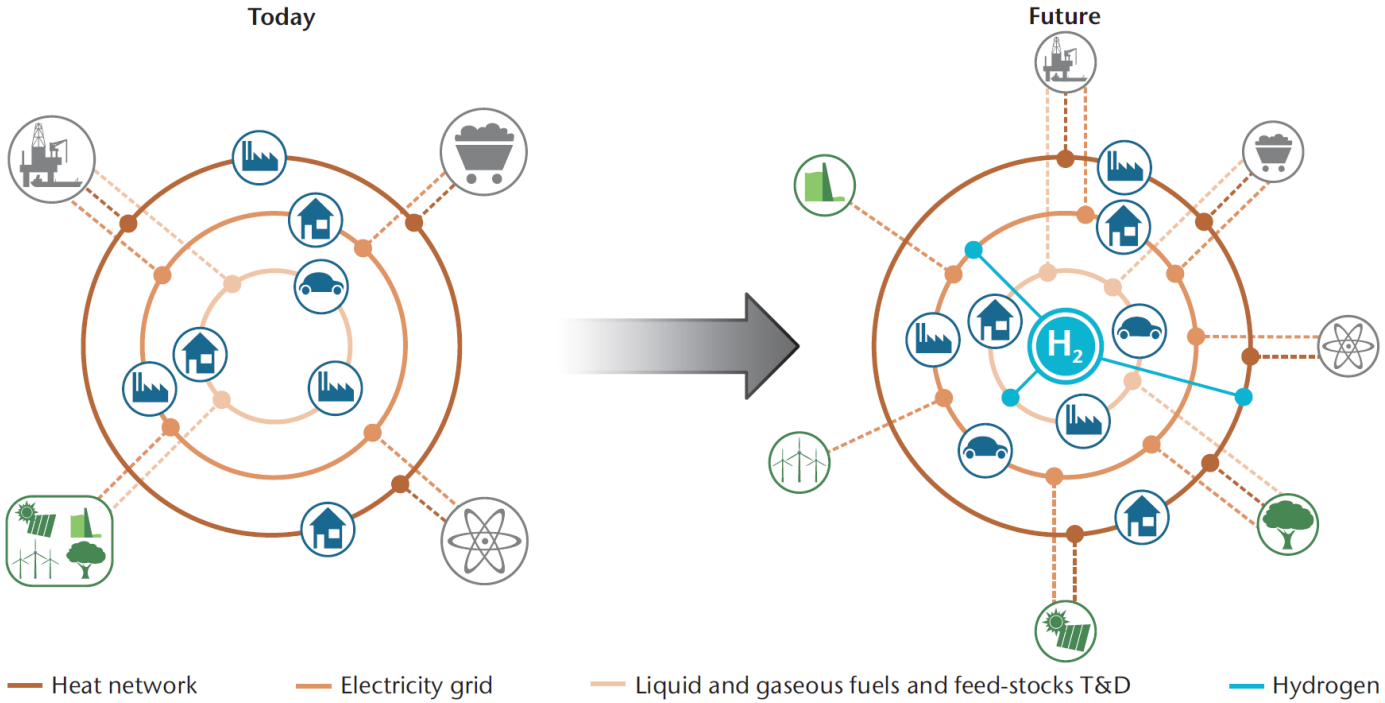
These can usually produce 50 - 200kg of hydrogen per day, which is stored in a battery of onsite pressurised tanks.

Some HRS use industrially produced hydrogen from steam reforming natural gas and ship it in to site.

Why bother?

Hydrogen is an **excellent** energy carrier.

It's not a primary energy source but can be used to store, transport and provide energy. Its energy density is high per unit mass. One of the advantages of hydrogen is that it can store energy from all sources, both renewable, fossil and even nuclear power – it's very flexible. Hydrogen is very likely to play a key role in the necessary transition from fossil fuels to a sustainable energy system.

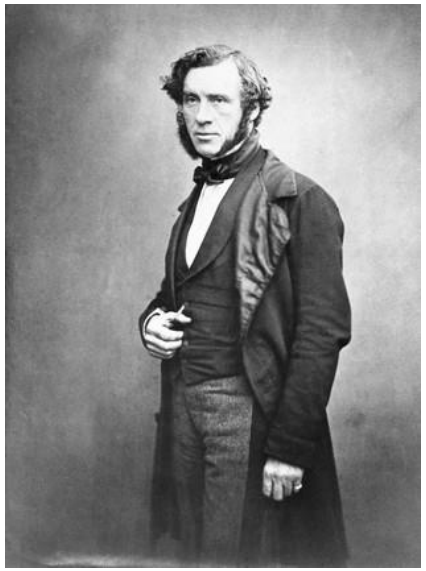


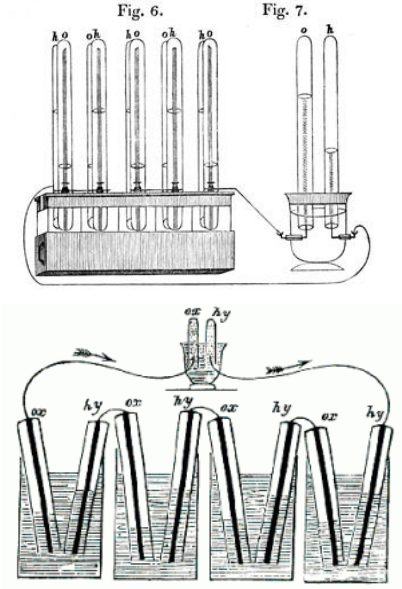
Infographic from IEA Technology Roadmap Hydrogen & Fuel Cells, 2015

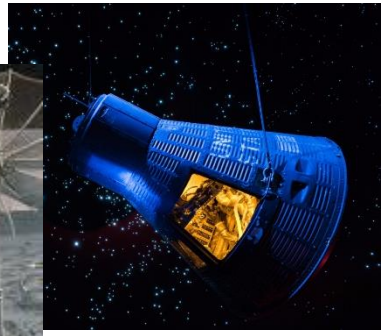
So, what's a fuel cell?

A fuel cell is an energy converter that efficiently transforms the chemical energy in hydrogen to electricity and heat. The only other product is pure water.
The fuel cell reaction is the equal and opposite reaction to electrolysis.

The principle was first demonstrated by Sir William Grove in 1842 but remained 'interesting' but without a practical application until the space programmes in the 1960s.







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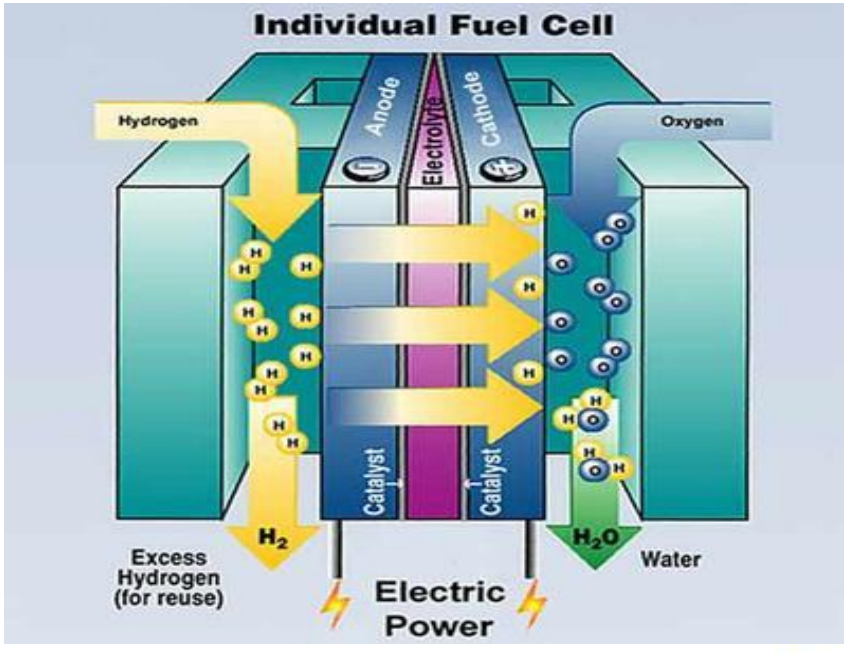
How does it work?

$2\ H2 \rightarrow 4H^+ + 4e^-$

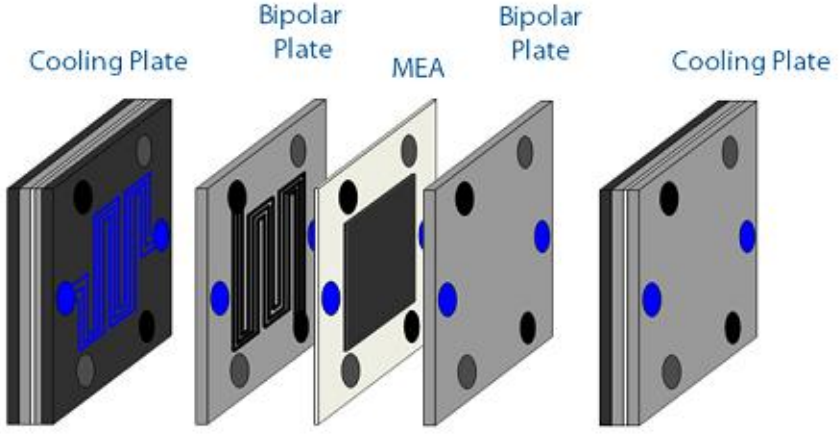


$O2 + 4H^+ + 4e^-$

$= 2\ H2O$

Fuel Cell Stack

Single Cell



Cell Components

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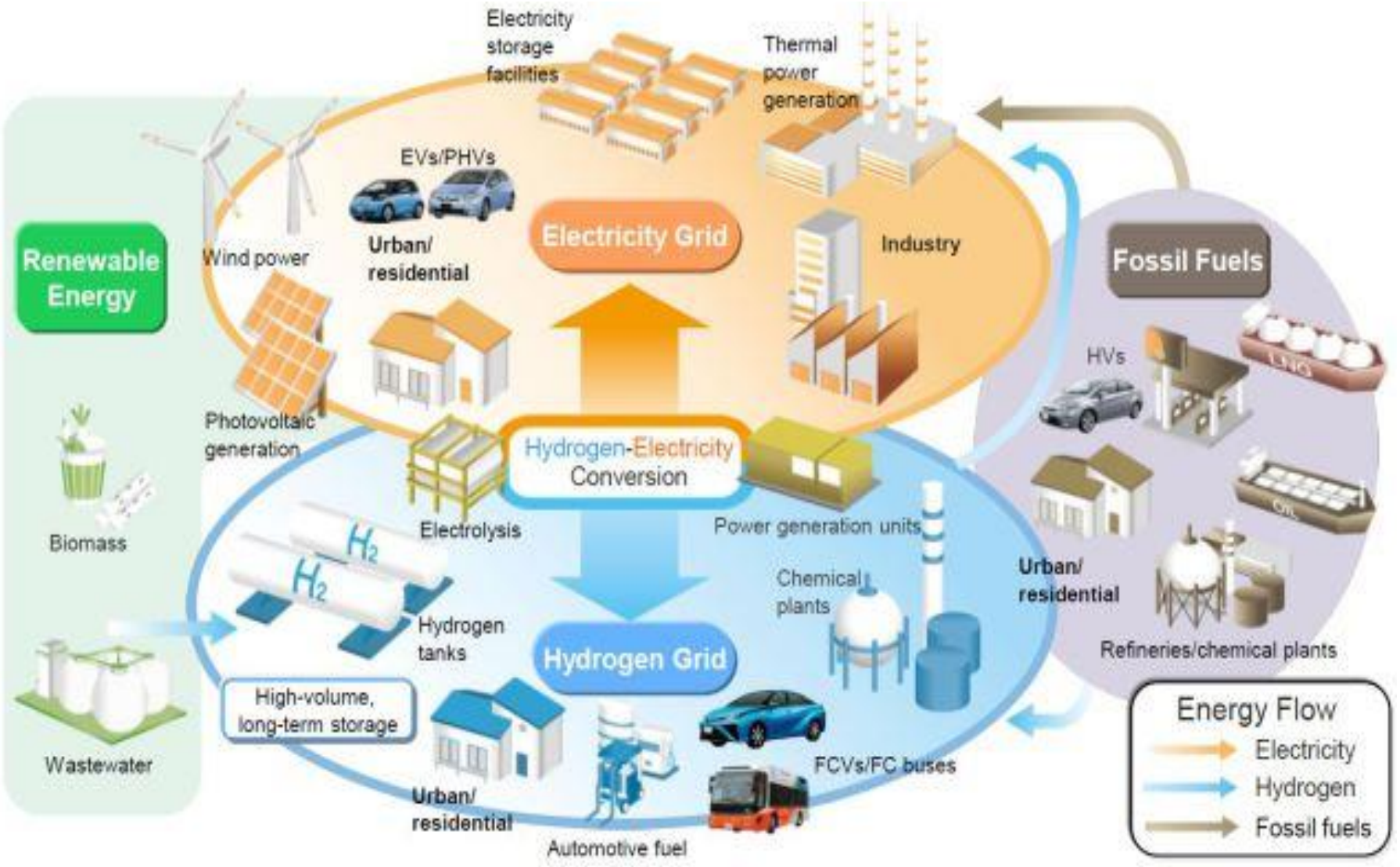
It’s just power…

www.fuelcellsystems.co.uk

The wider context



Infographic from newenergytreasure.com

Available fuel cell systems

25W – 3.7MW
Multi Technology:
Hydrogen, Methanol, Propane, Biogas, Natural Gas

Low Temperature

- DMFC – Direct Methanol – 75ºC
- PEM – Proton Exchange Membrane – 75ºC
- AFC – Alkaline Fuel Cells – 80ºC

High Temperature

- PAFC – Phosphoric Acid - 200ºC
- MCFC – Molten Carbonate Fuel Cell – 600ºC
- SOFC – Solid Oxide Fuel Cell – 1000ºC

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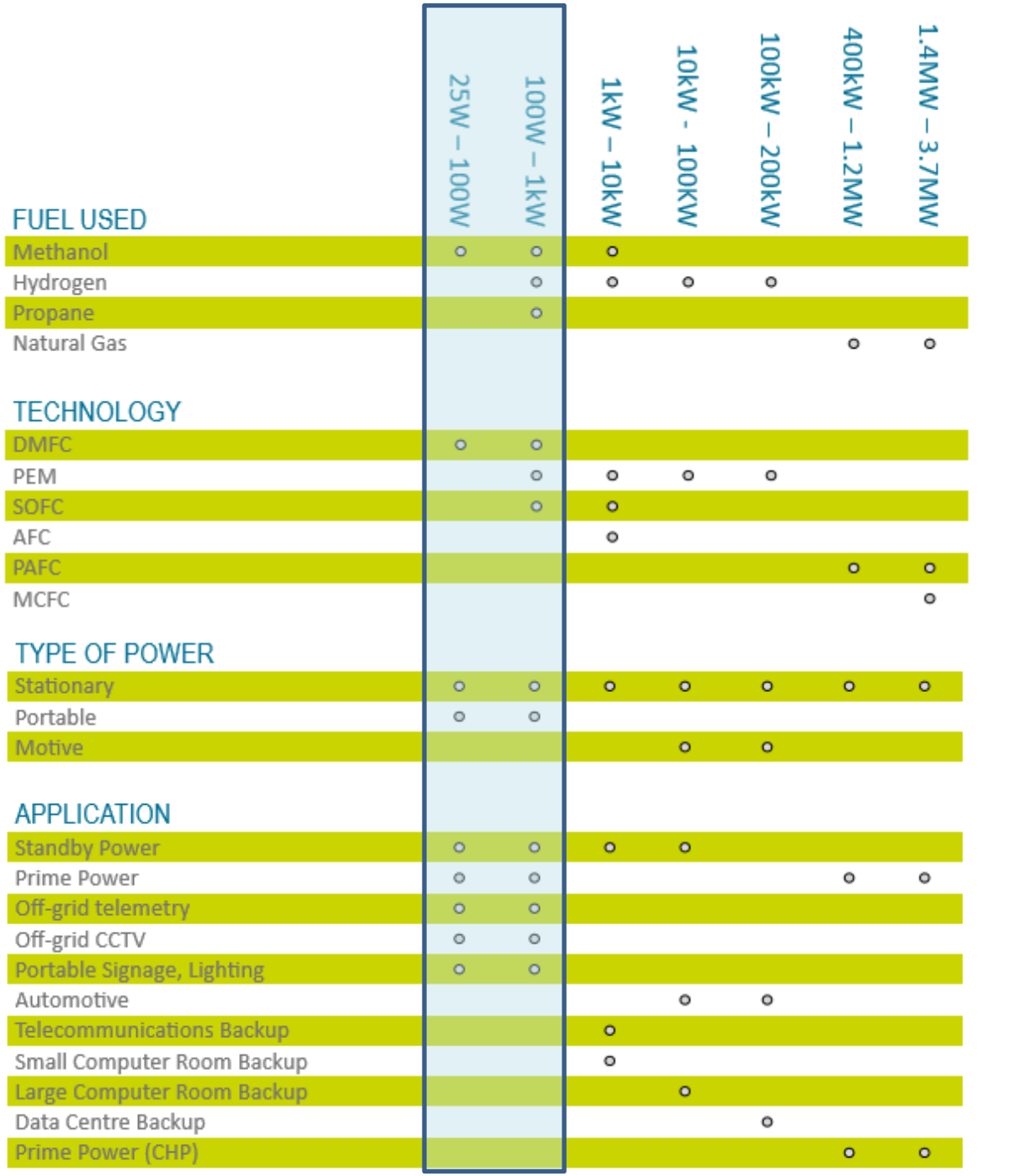
	25W – 100W	100W – 1kW	1kW – 10kW	10kW - 100KW	100kW – 200kW	400kW – 1.2MW	1.4MW – 3.7MW
FUEL USED							
Methanol	○	○	○				
Hydrogen		○	○	○	○		
Propane		○					
Natural Gas						○	○
TECHNOLOGY							
DMFC	○	○					
PEM		○	○	○	○		
SOFC		○	○				
AFC			○				
PAFC						○	○
MCFC							○
TYPE OF POWER							
Stationary	○	○	○	○	○	○	○
Portable	○	○					
Motive				○	○		
APPLICATION							
Standby Power	○	○	○	○			
Prime Power	○	○				○	○
Off-grid telemetry	○	○					
Off-grid CCTV	○	○					
Portable Signage, Lighting	○	○					
Automotive				○	○		
Telecommunications Backup			○				
Small Computer Room Backup			○				
Large Computer Room Backup				○			
Data Centre Backup					○		
Prime Power (CHP)						○	○

FUEL CELL SYSTEMS®



Available Products

	DMFC	SOFC	PEM	PEM
Power	< 100W	100W– 500W	100W – 250W	1KW-4KW
Capital Cost / W	£60 / W	£60 / W	£8 / W	£6 / W
Typical use	Low power application with long runtime	Medium power application with long runtime	Medium power application with short runtime	Medium to high power for short time; back-up power

CCTV Towers

- Rapid deployment / off-grid CCTV towers
- Typically short-term construction projects requiring security around the clock
- Batteries used alone require regular charging
- A fuel cell unit means reduced site visits for engineers
- Batteries can be charged silently throughout the night

FUEL CELL SYSTEMS®

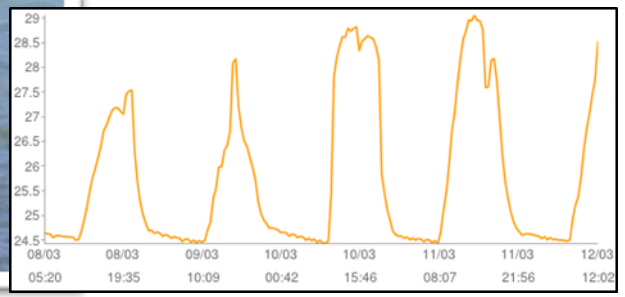
Environment Agency

"Fuel cells can be an ideal solution for powering most types of EA Hydrometry equipment. The EFOY Pro's ability to run in either 12 or 24VDC and it's all weather capability makes it a very useful tool. With the right housing the Pro can be deployed anywhere that monitoring is required"

Chris Barber, EA Hydrology

Environment Agency

Trinity House



- Light float with navigation equipment
- Solar panels for summer use
- Extra power required for winter months

BBC filming - Winterwatch

"The fuel cells were extremely quiet and the fact that we could leave them running for long periods of time meant that we were able to obtain some excellent rare footage of a pair of Golden Eagles arriving and roosting in a tree, along with some stunning and rarely captured Black Grouse behaviour. The environment-friendly nature of the technology also made it appealing."

Anna McGill, Production Manager

South Georgia Heritage Trust

- 110W DMFC in enclosure
- 100 days continuous running

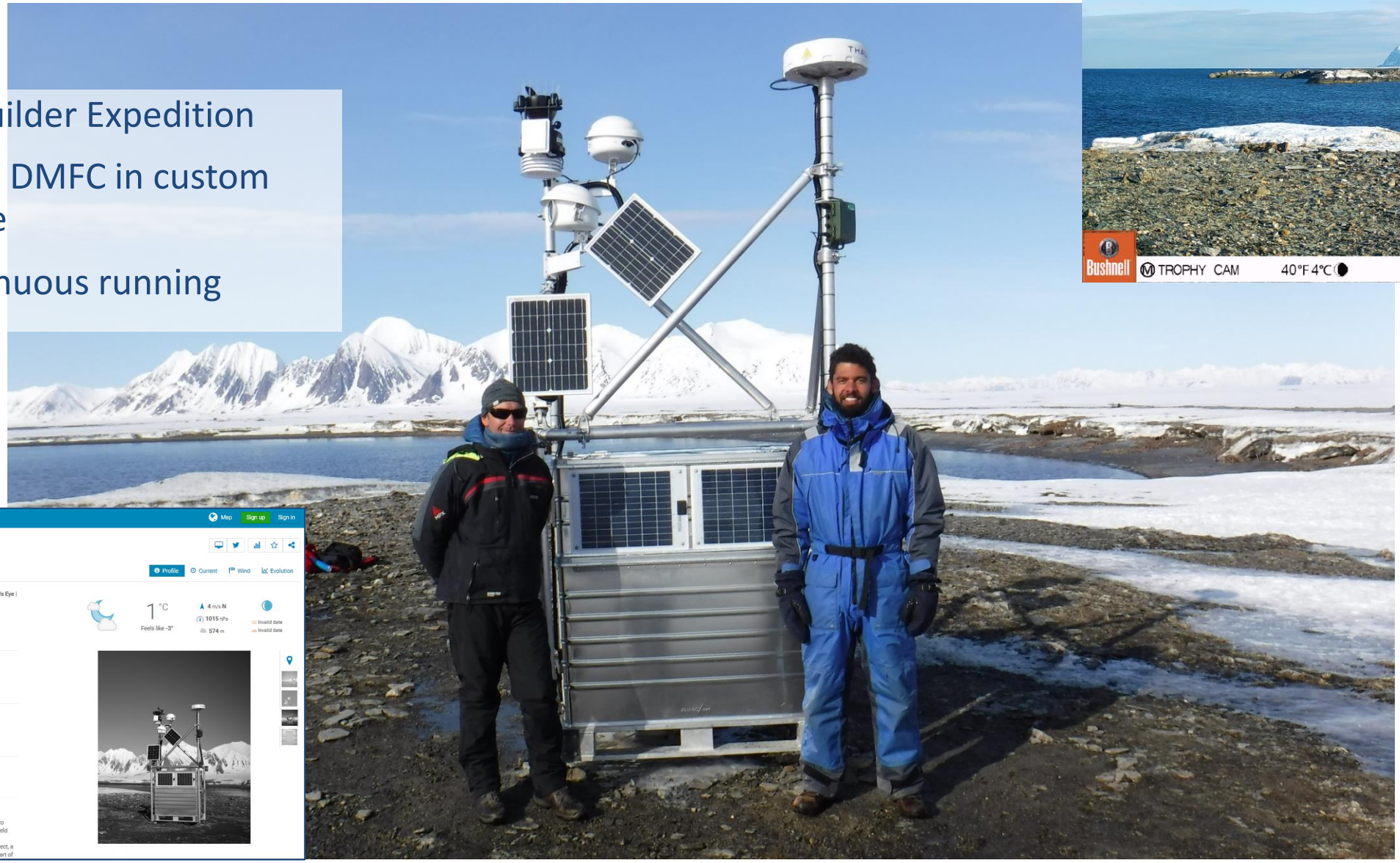
"The perfect deep-field solution for powering reliable safety communications in the sub Antartic"

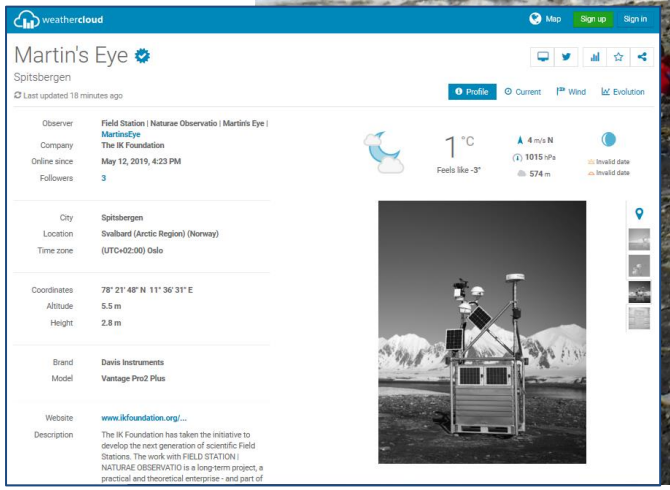
Rob Webster, Deputy Project Director

FUEL CELL SYSTEMS®

The IK Foundation

- Bridge Builder Expedition
- 3 x 110W DMFC in custom enclosure
- 6m continuous running





I K

FOUNDED IN 1988

FUEL CELL SYSTEMS®

	25W – 100W	100W – 1kW	1kW – 10kW	10kW - 100KW	100kW – 200kW	400kW – 1.2MW	1.4MW – 3.7MW
FUEL USED							
Methanol	○	○	○				
Hydrogen		○	○	○	○		
Propane		○					
Natural Gas						○	○
TECHNOLOGY							
DMFC	○	○					
PEM		○	○	○	○		
SOFC		○	○				
AFC			○				
PAFC						○	○
MCFC							○
TYPE OF POWER							
Stationary	○	○	○	○	○	○	○
Portable	○	○					
Motive				○	○		
APPLICATION							
Standby Power	○	○	○	○			
Prime Power	○	○				○	○
Off-grid telemetry	○	○					
Off-grid CCTV	○	○					
Portable Signage, Lighting	○	○					
Automotive				○	○		
Telecommunications Backup			○				
Small Computer Room Backup			○				
Large Computer Room Backup				○			
Data Centre Backup					○		
Prime Power (CHP)						○	○

Larger Stationary Power

FUEL CELL SYSTEMS®

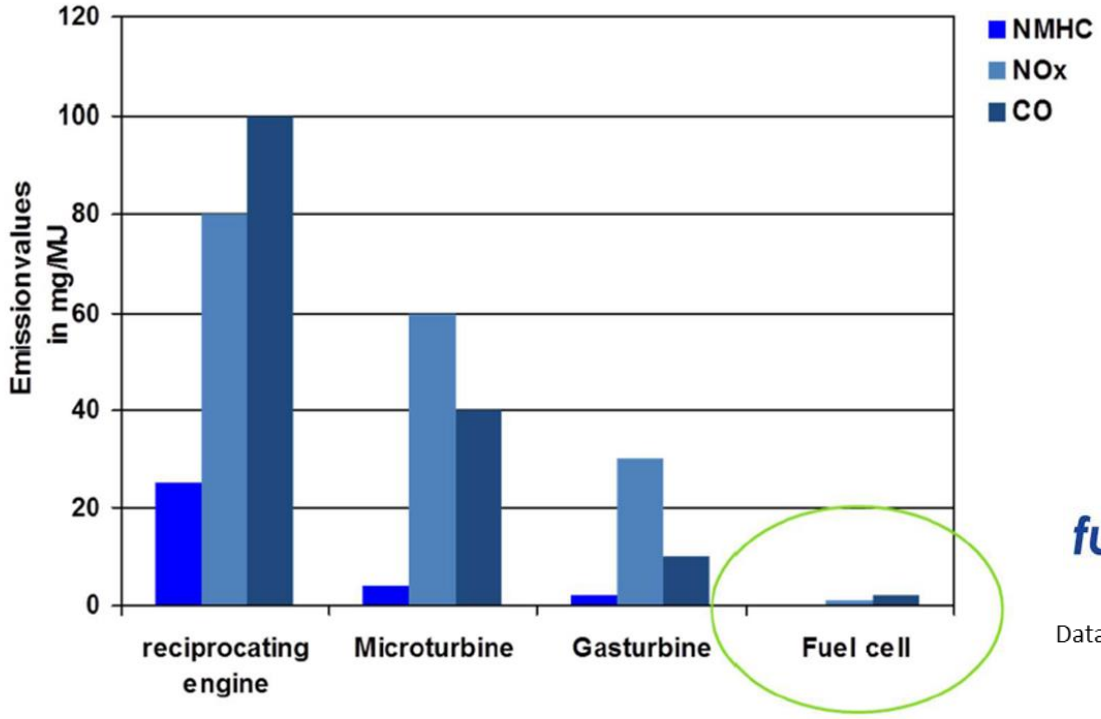
DIMES Feasibility Study

Funded by UK Government

This 12 month feasibility project investigated the techno-commercial benefits of integrating energy infrastructure with clean transport within the urban area of Bicester.

The conclusions were that fuel cell installations are more expensive than the incumbent technologies but are still profitable for the appointed ESCo under a thirty year management concession. In addition, the emissions for CO2, NOx, SOx and particulates are much lower than the incumbent technologies.

Fuel cells represent an additional distributed heat and power technology which can considerably lower emissions with a tolerable increased spend.



fuelcellenergy

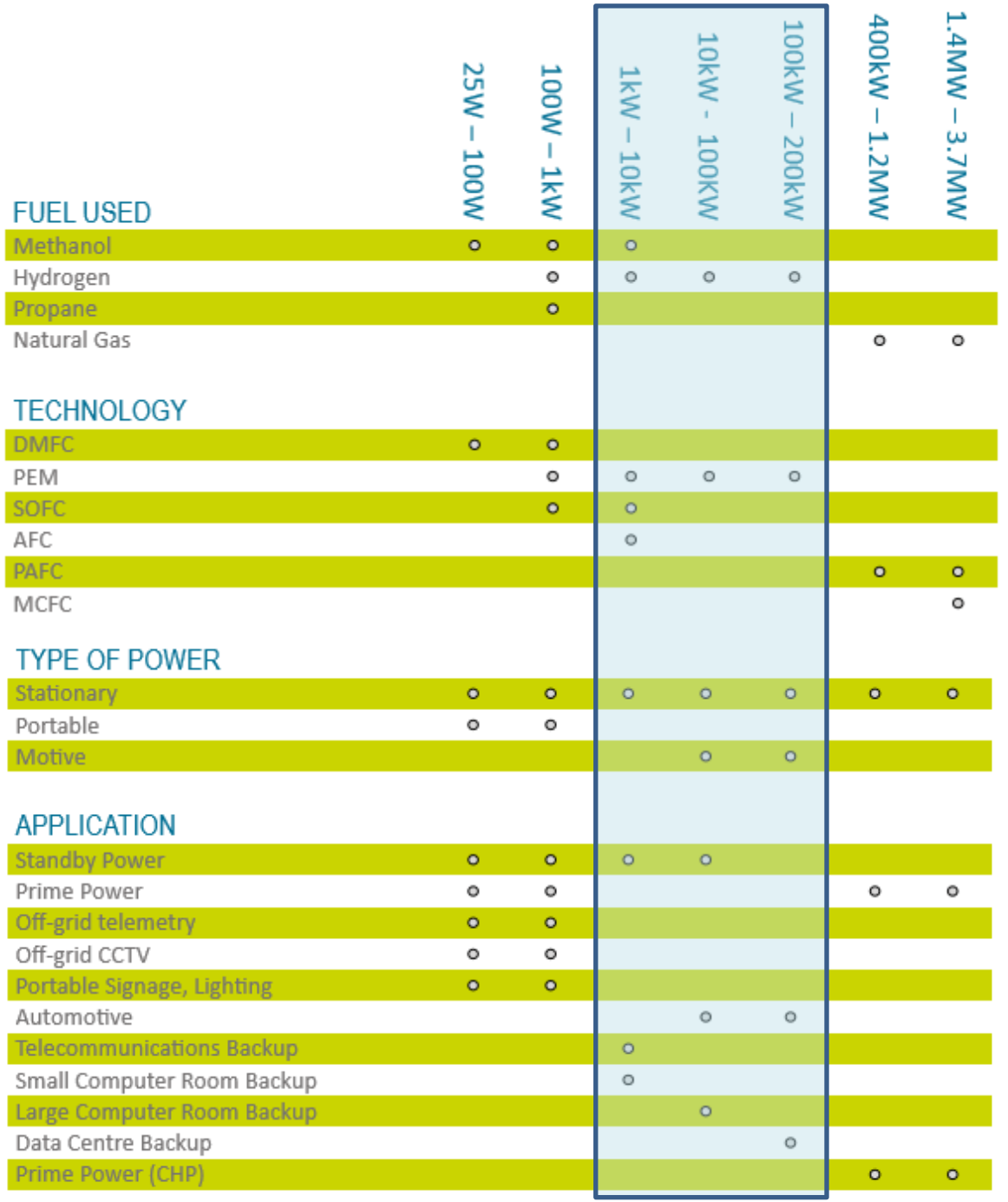
Data courtesy of Fuel Cell Energy Inc.

Fuel Cell Power for Urban Developments

Flexibility of installation	• Modular set-up to multi-MW, allowing for necessary redundancy • Choice of fuel, including natural gas and biogas
Flexibility of output	• Power only (20 year PPA available) • Heat and power • Heat, power and hydrogen offtake for vehicles
Higher efficiencies	• In addition to utilising the heat and electricity, waste water from the fuel cell can be reused in the grey water system in the development, escalating the BREEAM rating
Virtually zero emissions	• Better air quality, especially in terms of low NOx • Far less carbon emitted than from the combustion of gas in a CHP engine
Aid planning applications	• Compatible with 2017 National House Builders Council specifications
Workable financials	

Funded by UK Government

FUEL CELL SYSTEMS®



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This central section is predominantly hydrogen fuel cell technology. It encompasses the fuel cell buses, cars and fork lifts as well as smaller buildings.

The primary issue for these applications is how to get the hydrogen to the system.

	25W – 100W	100W – 1kW	1kW – 10kW	10kW - 100KW	100kW – 200kW	400kW – 1.2MW	1.4MW – 3.7MW
FUEL USED							
Methanol	o	o	o				
Hydrogen		o	o	o	o		
Propane		o					
Natural Gas						o	o
TECHNOLOGY							
DMFC	o	o					
PEM		o	o	o	o		
SOFC		o	o				
AFC			o				
PAFC						o	o
MCFC							o
TYPE OF POWER							
Stationary	o	o	o	o	o	o	o
Portable	o	o					
Motive				o	o		
APPLICATION							
Standby Power	o	o	o	o			
Prime Power	o	o				o	o
Off-grid telemetry	o	o					
Off-grid CCTV	o	o					
Portable Signage, Lighting	o	o					
Automotive				o	o		
Telecommunications Backup			o				
Small Computer Room Backup			o				
Large Computer Room Backup				o			
Data Centre Backup					o		
Prime Power (CHP)						o	o

FUEL CELL SYSTEMS®

SWISH Education Centre

Funded by UK Government

Fuel Cell Systems Ltd design and deliver the UK's first fully integrated portable building powered by fuel cell and solar generated hydrogen.

BOC A Member of The Linde Group

BRIGGS EQUIPMENT UK

COMMERCIAL GROUP

HONDA The Power of Dreams

ENOVE The centre of excellence

Swindon Borough Council

FUEL CELL SYSTEMS

SWISH2

Funded by UK Government

Fuel Cell Systems Ltd design and deliver the UK's first fully integrated portable building powered by fuel cell and solar generated hydrogen.

3 kW fuel cell installation -
hydrogen already available onsite

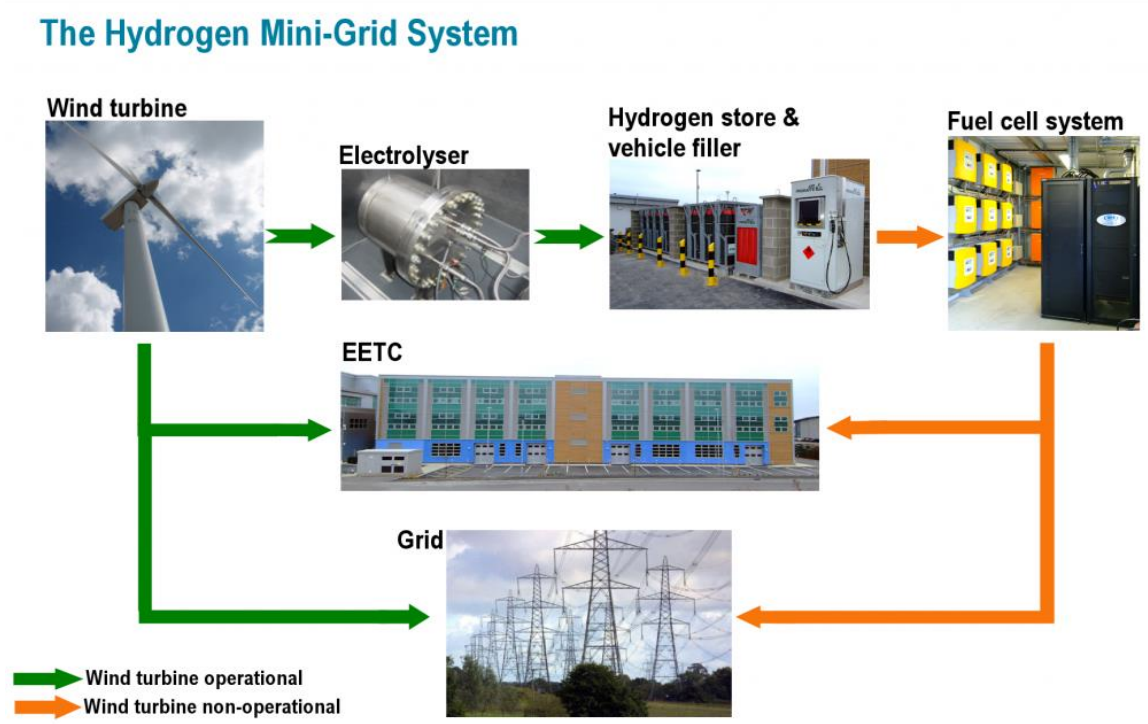
BOC
BRIGGS EQUIPMENT UK
GROUP
HONDA
Swindon

www.fuelcellsystems.co.uk

Rotherham EETC

Funded by UK Government

When energy consultants TNEI were asked to create the UK's first fully-hybridised, stand-alone and completely 'green' **hydrogen mini-grid**, Fuel Cell Systems Ltd were called upon to specify, supply, install and commission the fuel cell system designed to co-power the new Environmental Energy Technology Centre (EETC) in Rotherham, South Yorkshire.



FUEL CELL SYSTEMS

Rotherham EECT

Funded by UK Government

When energy consultants TNEI were asked to create the UK's first fully-hybridised, stand-alone and completely 'green' hydrogen mini-grid, Fuel Cell Systems Ltd were called upon to specify, supply, install and commission the fuel cell system designed to co-power the new [illegible] Technology Centre (EETC) in [illegible]

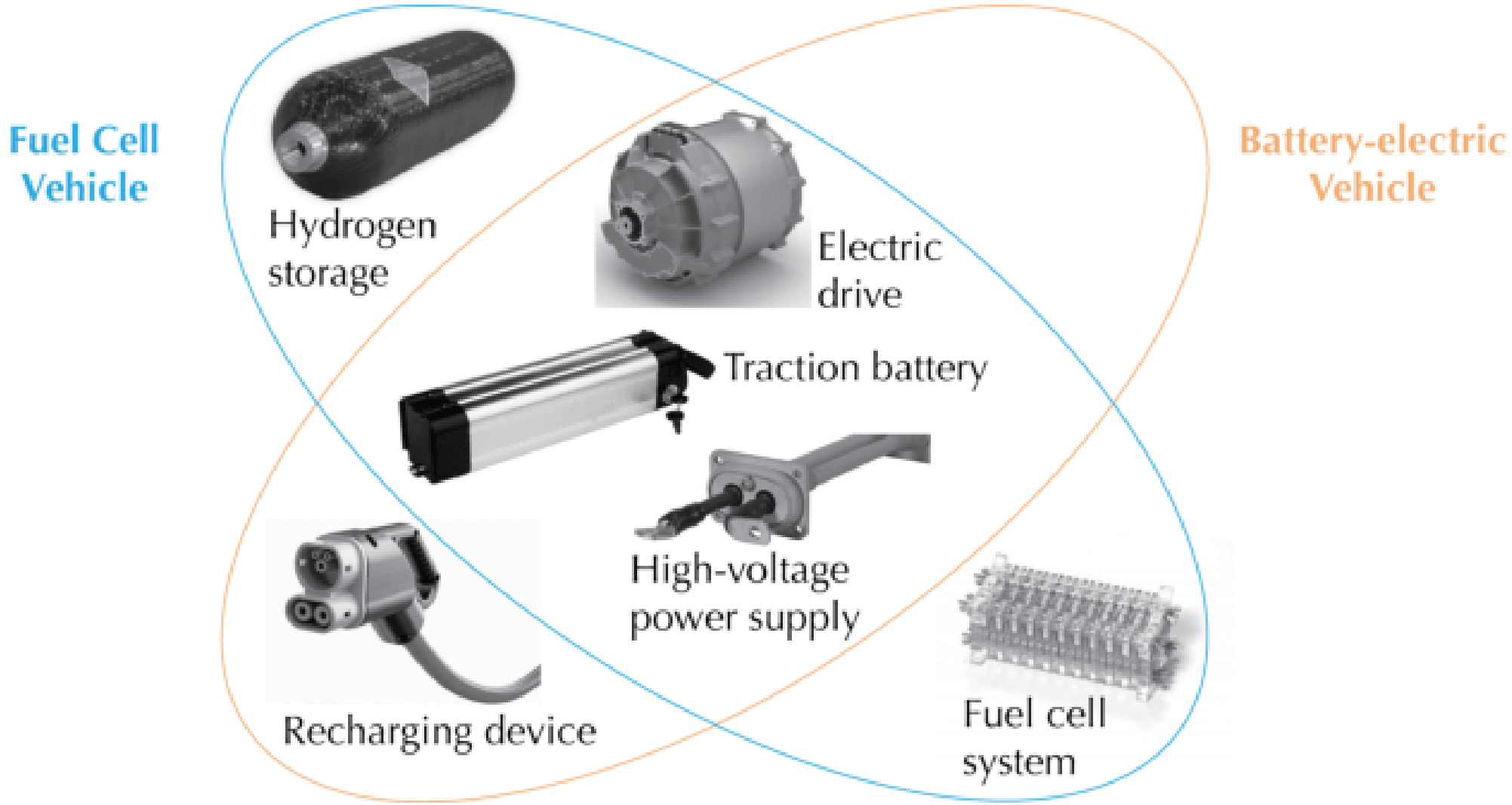
36 kW fuel cell installation - hydrogen already available onsite

www.fuelcellsystems.co.uk

FUEL CELL SYSTEMS®

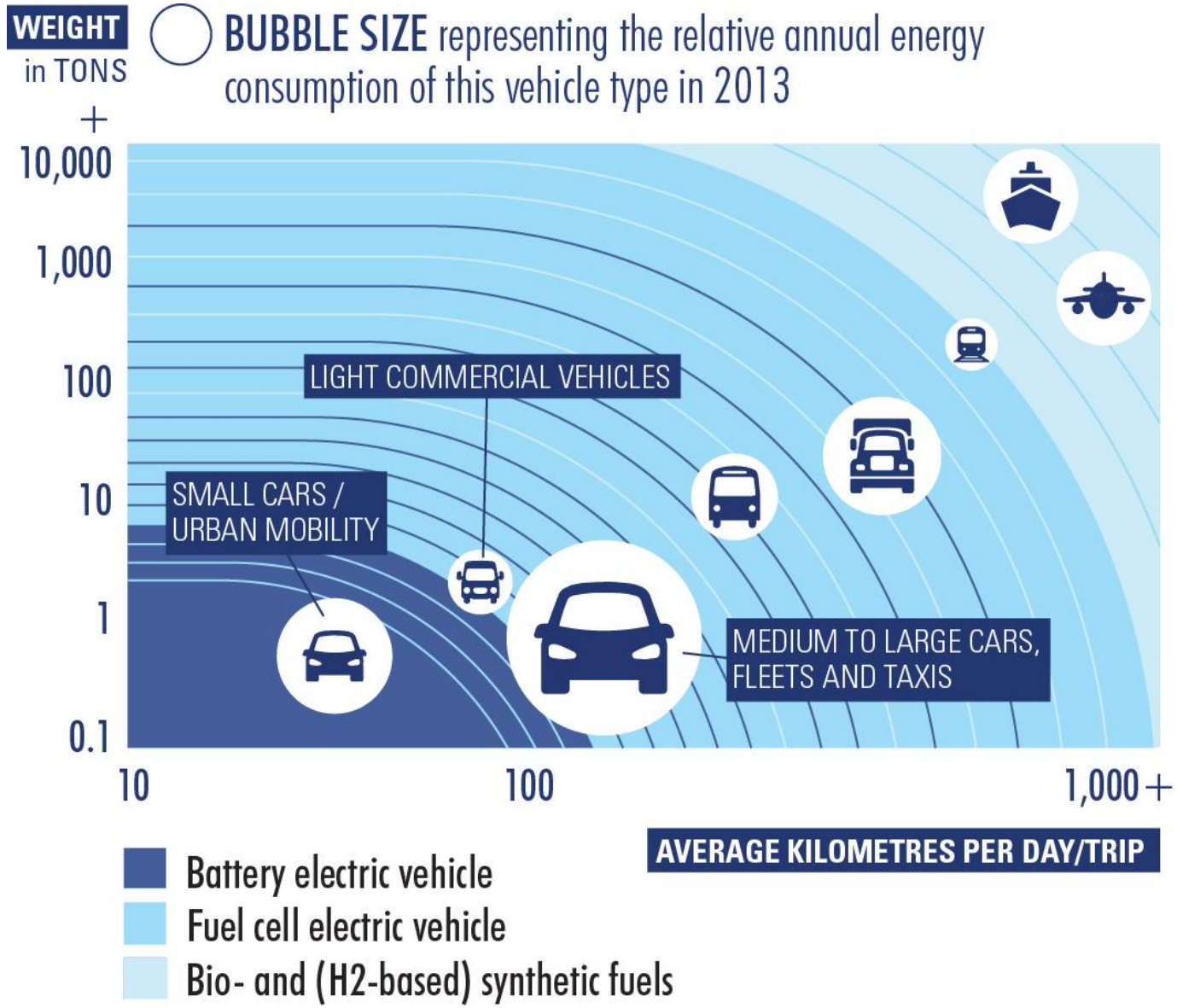
Hydrogen transport

Electricity and Hydrogen are symbiotic



Infographic from researchgate.net

Propulsion technology types



Infographic from hydroville.be

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Hydrogen Refuelling

Refuelling Product Spectrum

HySerVE

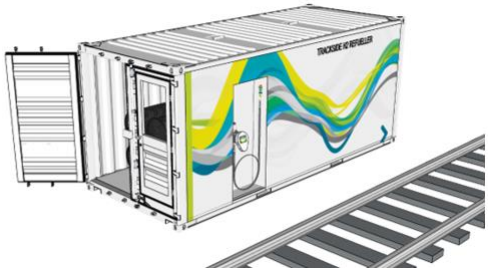
Mini Hydrogen Dispenser

50 miles

OLEV Truck

Mobile HRS

60kg storage w compression



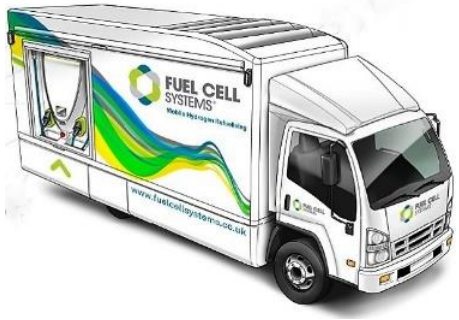
Full Static Station

Hydrogen producing fully installed station

HyVan

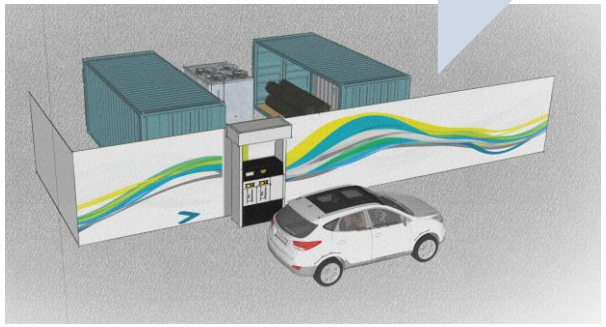
Compact Mobile HRS

22kg storage



Temporary HRS

Containerised station with external hydrogen



Toyota Mirai Refuelling

The Toyota Mirai launched in the UK from mid-2015. As more cars became available for the European markets during 2018, further marketing activities were introduced.

AUTOCAR

John O'Groats to Land's End in a hydrogen fuel cell car

The hydrogen fuel cell Toyota Mirai could be the future, but how does it fare on British roads today?

Suzuki Scooter Refuelling

The Metropolitan Police agreed to trial 7 fuel cell Suzuki Bergman scooters from October 2017 until December 2018. They required hydrogen fuel in a central London location for this period.

HyFlyer Refuelling

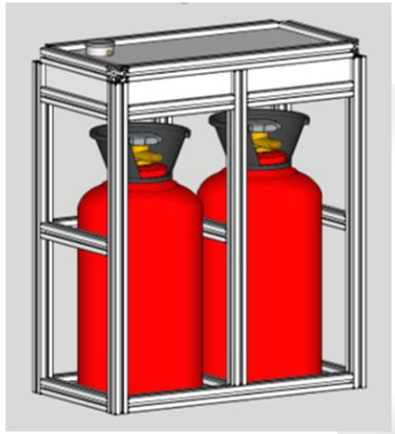
The HyFlyer project will demonstrate hydrogen fuel cell powertrain technology for zero-emission aviation. The project will integrate a hydrogen fuel cell powertrain on board a Piper M-class six-seater aircraft and perform test flights out of Cranfield and Orkney.

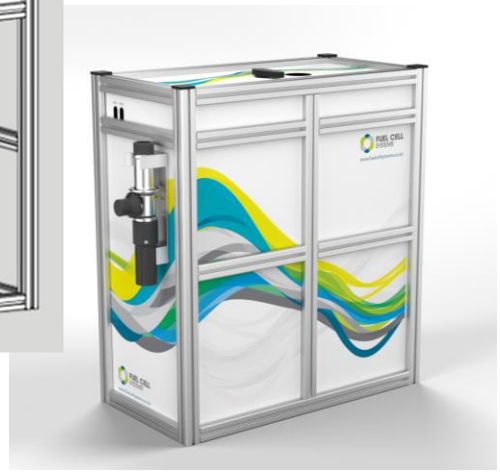
EMEC
THE EUROPEAN MARINE ENERGY CENTRE LTD

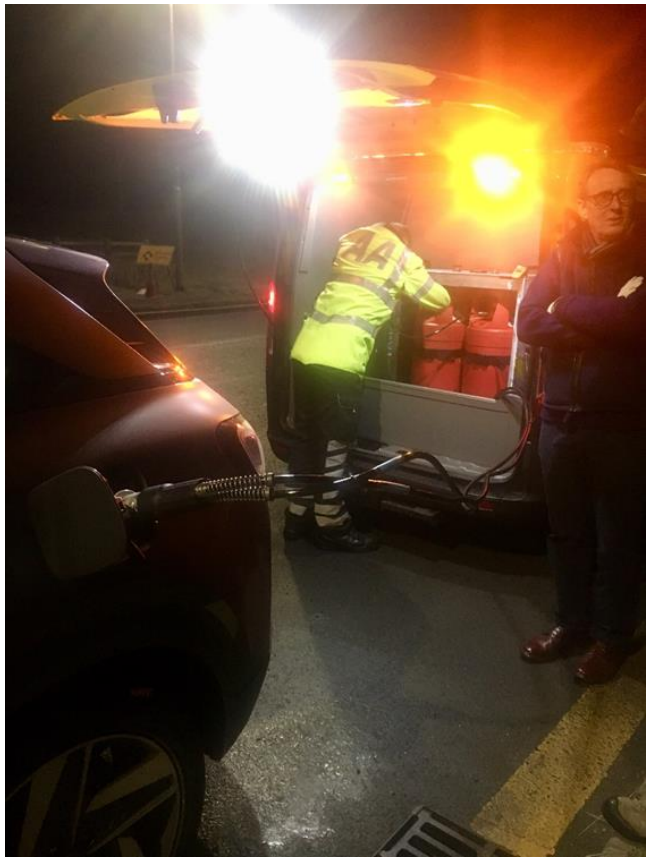
ZEROAVIA

FUEL CELL SYSTEMS®

Mini Hydrogen Dispenser







infocus
WOMEN IN INNOVATION

Funded by
UK Government

Telegraph Nexo 1000 Mile Trial

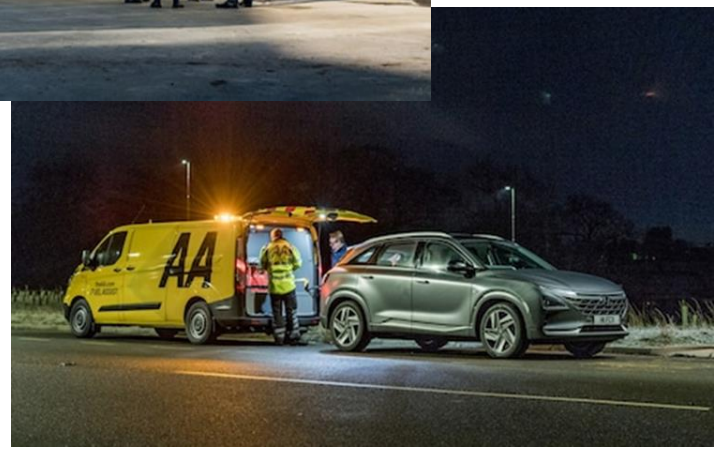
The Telegraph

Lifestyle › Cars › Features

Can a hydrogen fuel-cell car master the 1,000-Mile Trial?

share

Save 74



HYUNDAI

AA

HyQube Solution

The FCSL HyQube is available in a few configurations. They can take any hydrogen input feed, and dispense automated, non-chilled fills but compliant with J2601-2010.

Basic HyQube 350
Direct boost, overnight non-communicative fill to 350bar.
Lead time 3-6m. Price £60k

HyQube 350+

Includes storage to enable a non-communicative cascade fill (faster, more similar to static HRS).

Lead time 3-6m. Price £90k.

HyQube 500
Includes more storage to enable a cascade fill with IR communication. Requires a small amount of direct boosting following the cascade to get to the full 500 bar.

Lead time 3-6m. Price £120k.
Working towards CE certification, with plans to have this in place within 2021.

HydroFLEX Train Fuelling

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NEWS

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Business Your Money Market Data Companies Economy

All aboard Britain's first hydrogen train

By Tom Burridge
Transport correspondent, BBC News

20 June 2019 Share

Hydrogen-powered trains are arguably the greenest trains out there.

The HydroFLEX train project started by using the FCSL mobile refuelling truck to provide onsite fuelling.

They have now purchased a basic HyQube 350.

FUEL CELL SYSTEMS®

Any questions?

Thank you

Tom Sperrey
tsperrey@fuelcellsystems.co.uk

Richard Stockwell
rstockwell@fuelcellsystems.co.uk

Henry Mills
hmills@fuelcellsystems.co.uk

Beth Dawson
bdawson@fuelcellsystems.co.uk