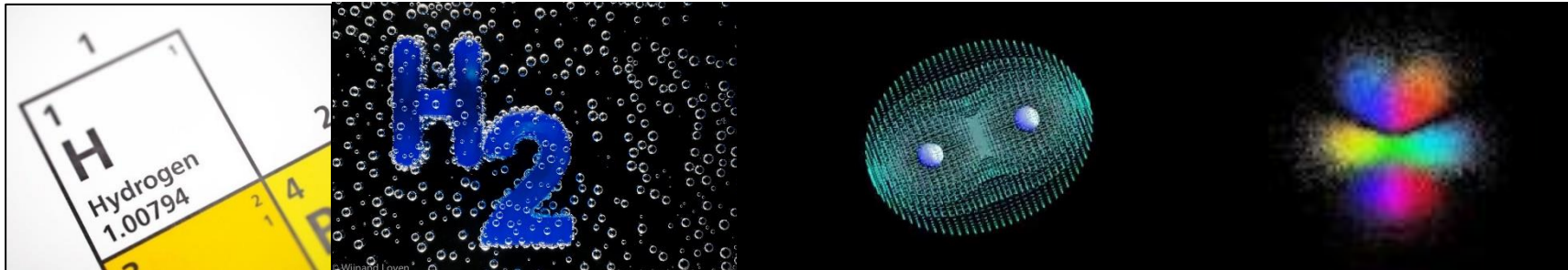




Introduction to Hydrogen and Fuel Cells

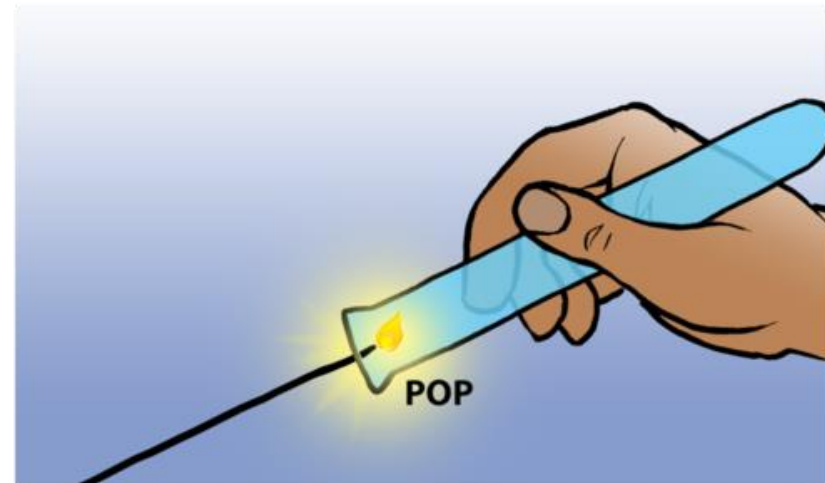
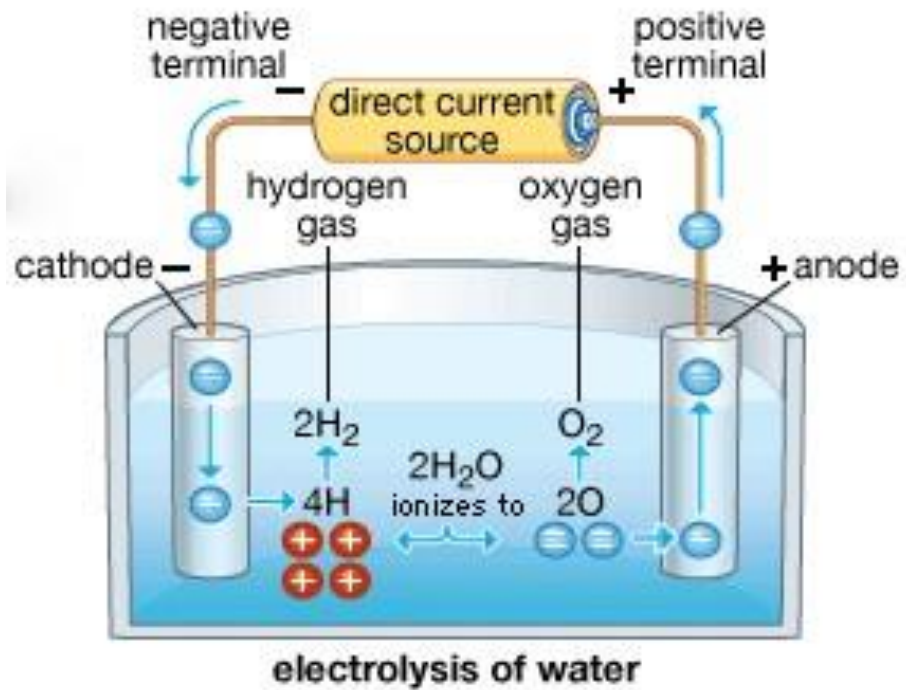
Hydrogen

- 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 H₂.
- 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.



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 split water.

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

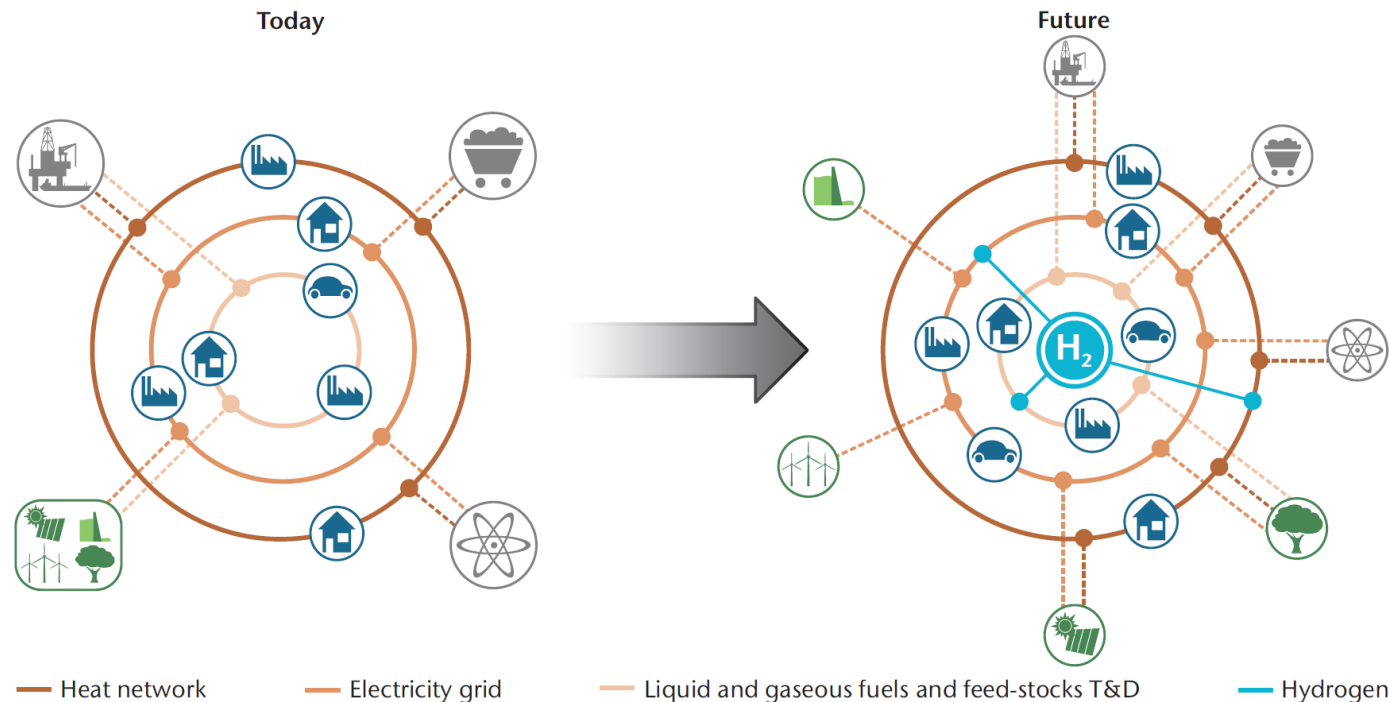
Some HRS use industrially produced hydrogen from steam reforming natural gas and ship it in to site.



Why bother?

Hydrogen is an **excellent** energy carrier.

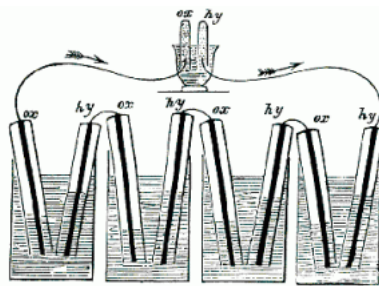
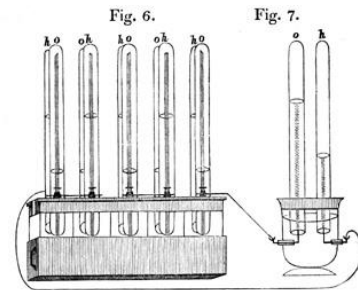
It's not a primary energy source but can be used to store, transport and provide energy. Its energy density is high per unit mass. One of the advantages of hydrogen is that it can store energy from all sources, both renewable, fossil and even nuclear power – it's very flexible. Hydrogen is very likely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



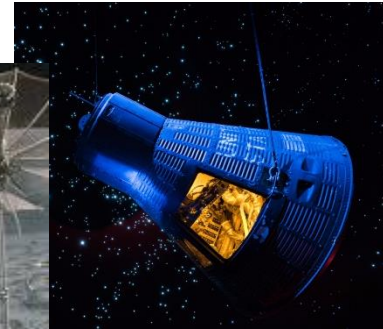
So, what's a fuel cell?

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.

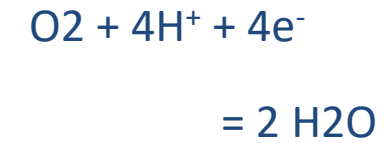
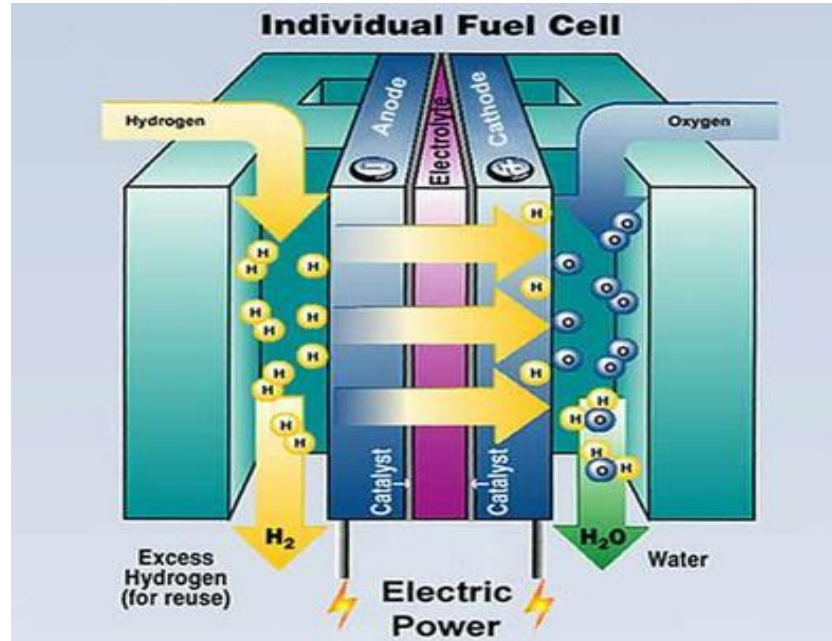
The principle was first demonstrated by Sir William Grove in 1842 but remained 'interesting' but without a practical application until the space programmes in the 1960s.



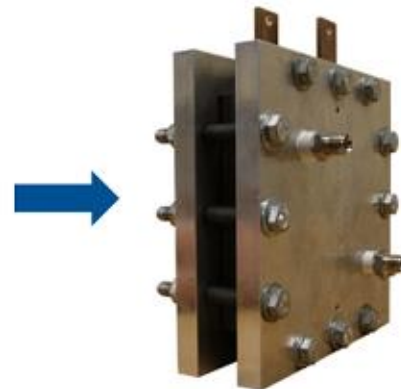
www.fuelcellsystems.co.uk



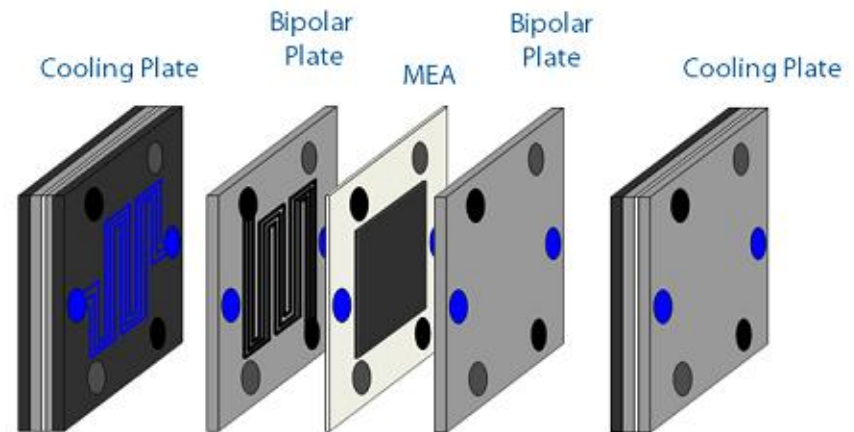
How does it work?



Fuel Cell Stack

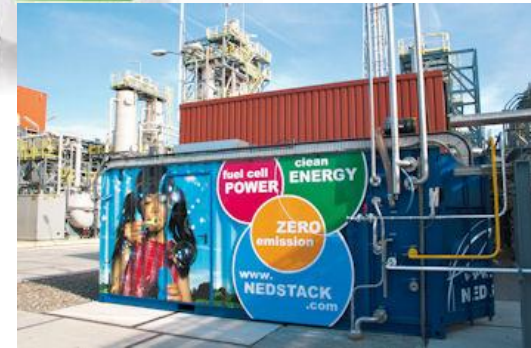
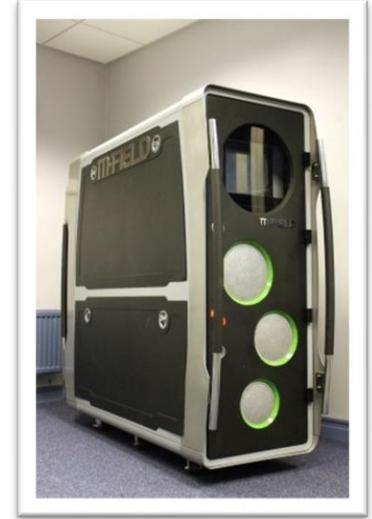


Single Cell

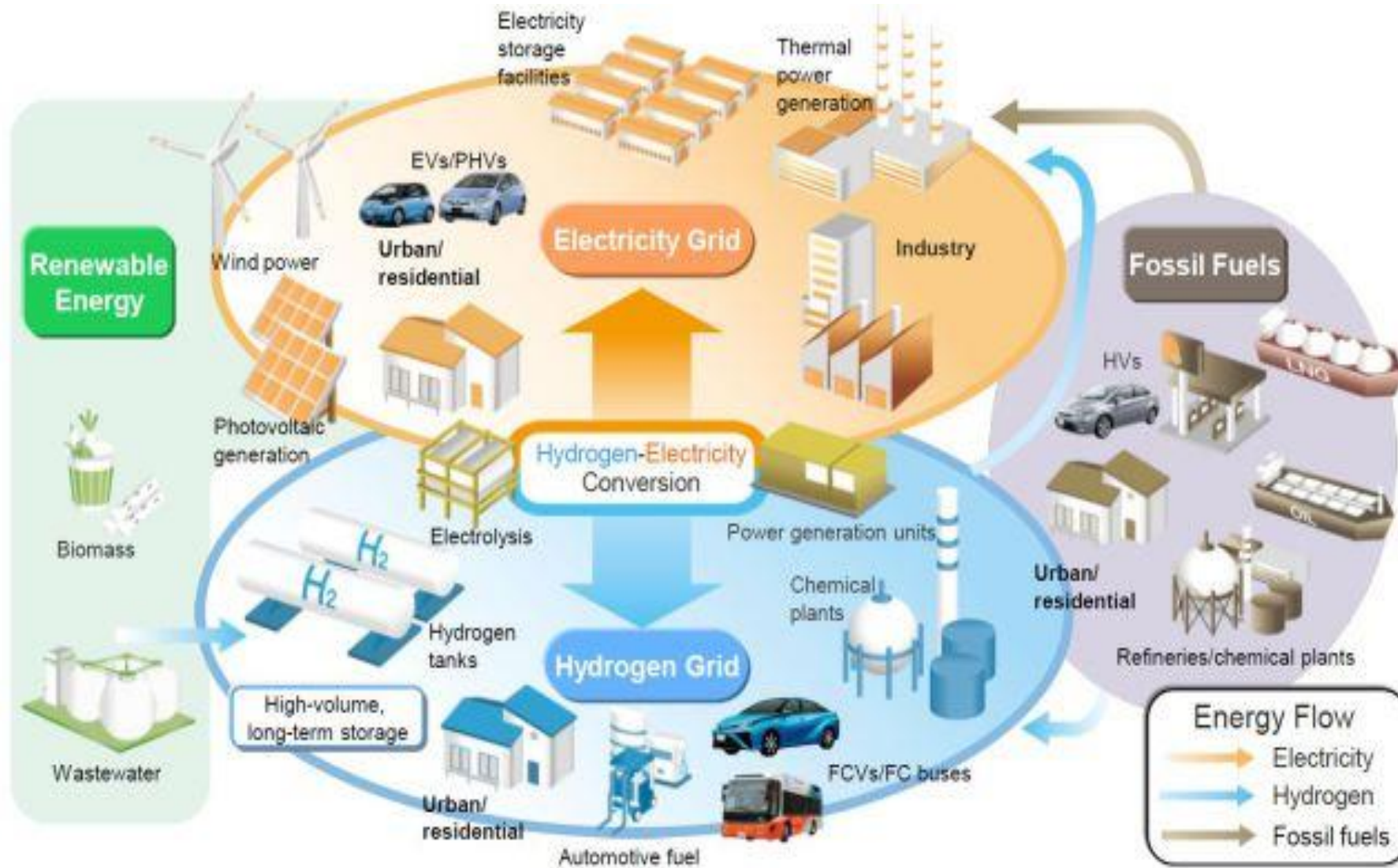


Cell Components

It's just power...



The wider context



Available fuel cell systems

25W – 3.7MW

Multi Technology:

Hydrogen, Methanol, Propane, Biogas, Natural Gas

Low Temperature

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

High Temperature

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



	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)						○	○



	25W – 100W	100W – 1kW	1kW – 10kW	10kW - 100kW	100kW – 200kW	400kW – 1.2MW	1.4MW – 3.7MW
FUEL USED							
Methanol	○	○	○				
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TECHNOLOGY							
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Telecommunications Backup			○				
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Large Computer Room Backup				○			
Data Centre Backup					○		
Prime Power (CHP)						○	○

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

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”

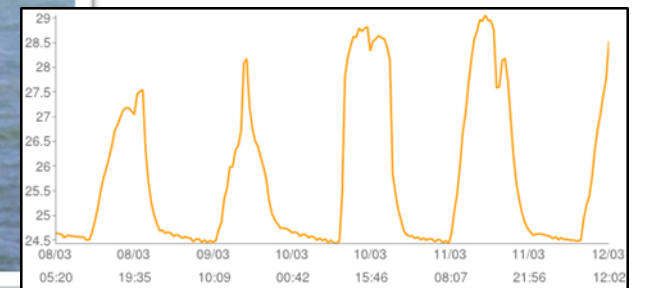
Chris Barber, EA Hydrology



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

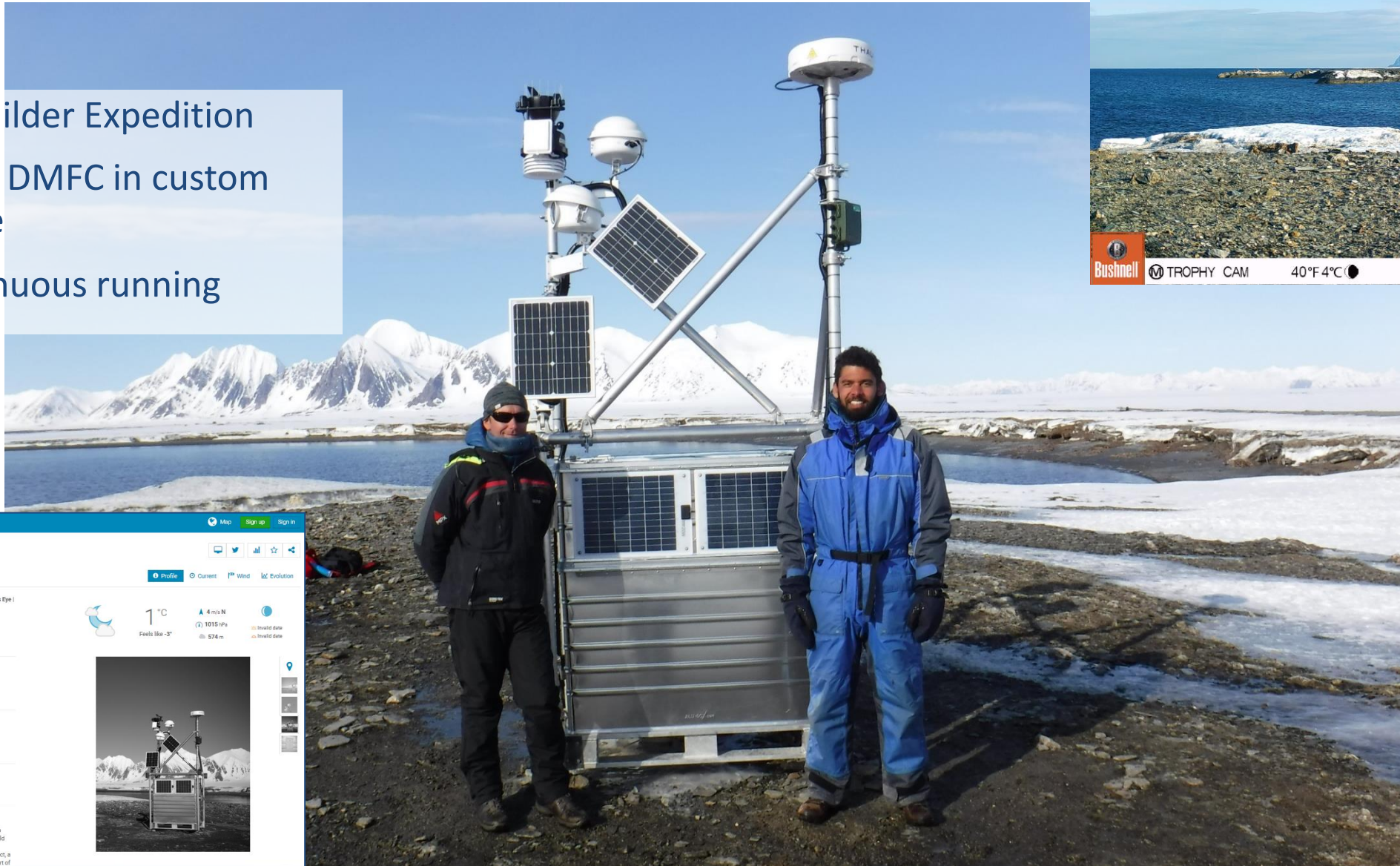
“The perfect deep-field solution for powering reliable safety communications in the sub Antarctic”

Rob Webster, Deputy Project Director




The IK Foundation

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



weathercloud

Martin's Eye 

Spitsbergen

Last updated 18 minutes ago

Profile Current Wind Evolution

Observer	Field Station Naturae Observatio Martin's Eye
Company	Martin's Eye
Online since	The IK Foundation
Followers	May 12, 2019, 4:23 PM
	3


City: Spitsbergen
Location: Svalbard (Arctic Region) (Norway)
Time zone: (UTC+02:00) Oslo

Coordinates: 78° 21' 48" N 11° 36' 31" E
Altitude: 5.5 m
Height: 2.8 m

Brand: Davis Instruments
Model: Vantage Pro2 Plus

Website: [www.ikfoundation.org/...](http://www.ikfoundation.org/)

Description: The IK Foundation has taken the initiative to develop the next generation of scientific Field Stations. The work with FIELD STATION | NATURAE OBSERVATIO is a long term project, a practical and theoretical enterprise - and start of

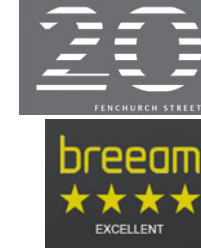



FOUNDED IN 1988



	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	○	○					
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Automotive				○	○		
Telecommunications Backup			○				
Small Computer Room Backup			○				
Large Computer Room Backup				○			
Data Centre Backup					○		
Prime Power (CHP)						○	○

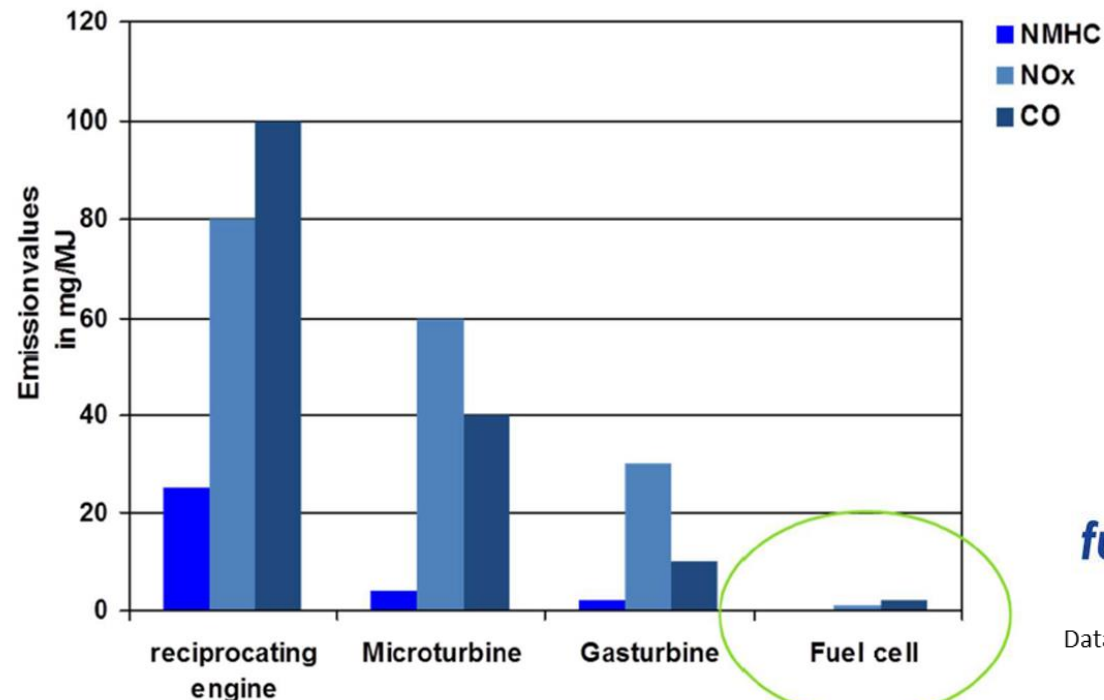
Larger Stationary Power



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, NO_x, SO_x 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.





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





	25W – 100W	100W – 1kW	1kW – 10kW	10kW - 100kW	100kW – 200kW	400kW – 1.2MW	1.4MW – 3.7MW
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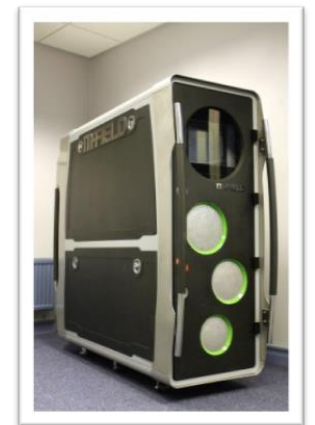


This central section is predominantly hydrogen fuel cell technology. It encompasses the fuel cell buses, cars and fork lifts as well as smaller buildings.

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	○	○	○	○	○		
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Propane		○					
Natural Gas						○	○
TECHNOLOGY							
DMFC	○	○					
PEM		○	○	○	○		
SOFC		○	○				
AFC			○				
PAFC						○	○
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Automotive				○	○		
Telecommunications Backup			○				
Small Computer Room Backup			○				
Large Computer Room Backup				○			
Data Centre Backup					○		
Prime Power (CHP)						○	○



SWISH Education Centre

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





SWISH2



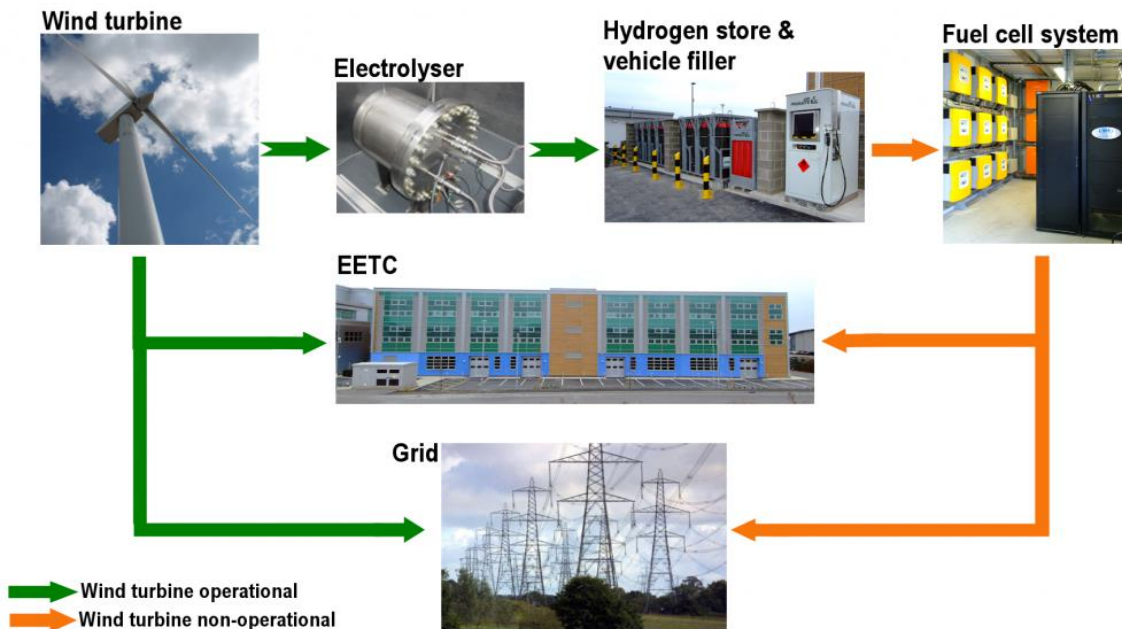
Fuel Cell Systems Ltd design and deliver the UK's first fully integrated portable building powered by fuel cell and solar generated hydrogen.



www.fuelcellsystems.co.uk

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.

The Hydrogen Mini-Grid System



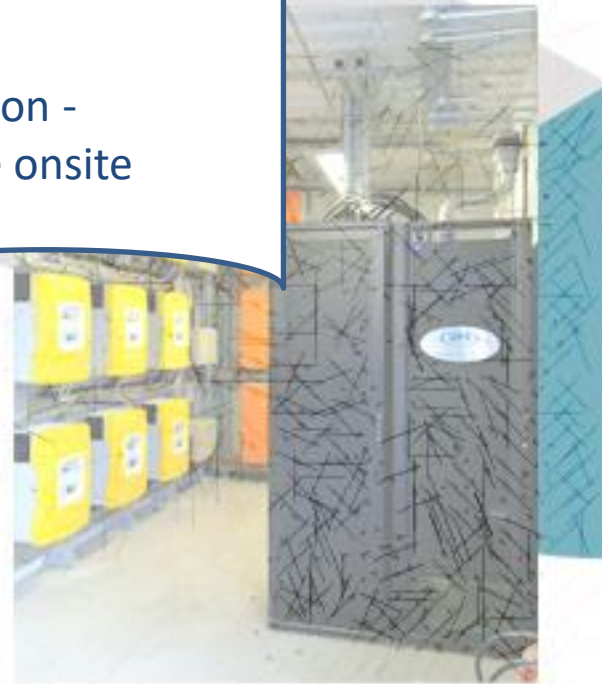
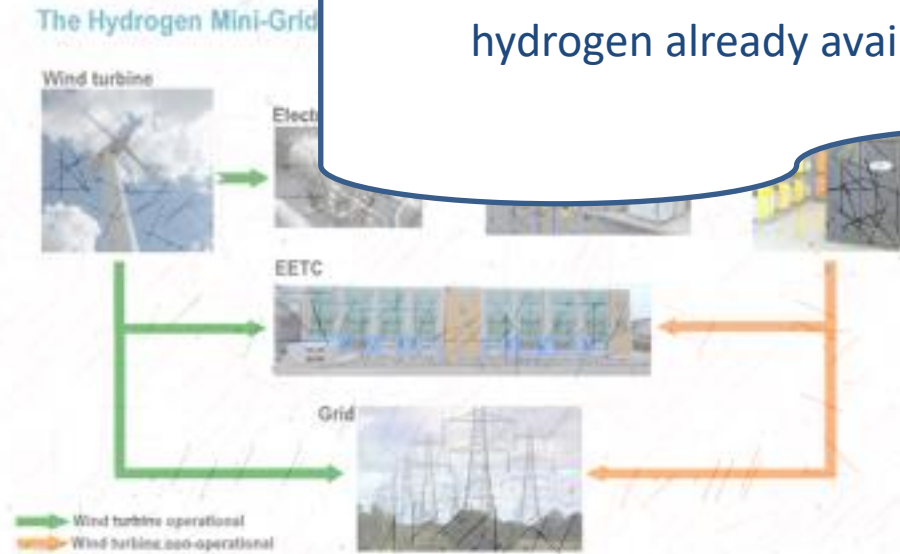


Rotherham EECT



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36 kW fuel cell installation -
hydrogen already available onsite

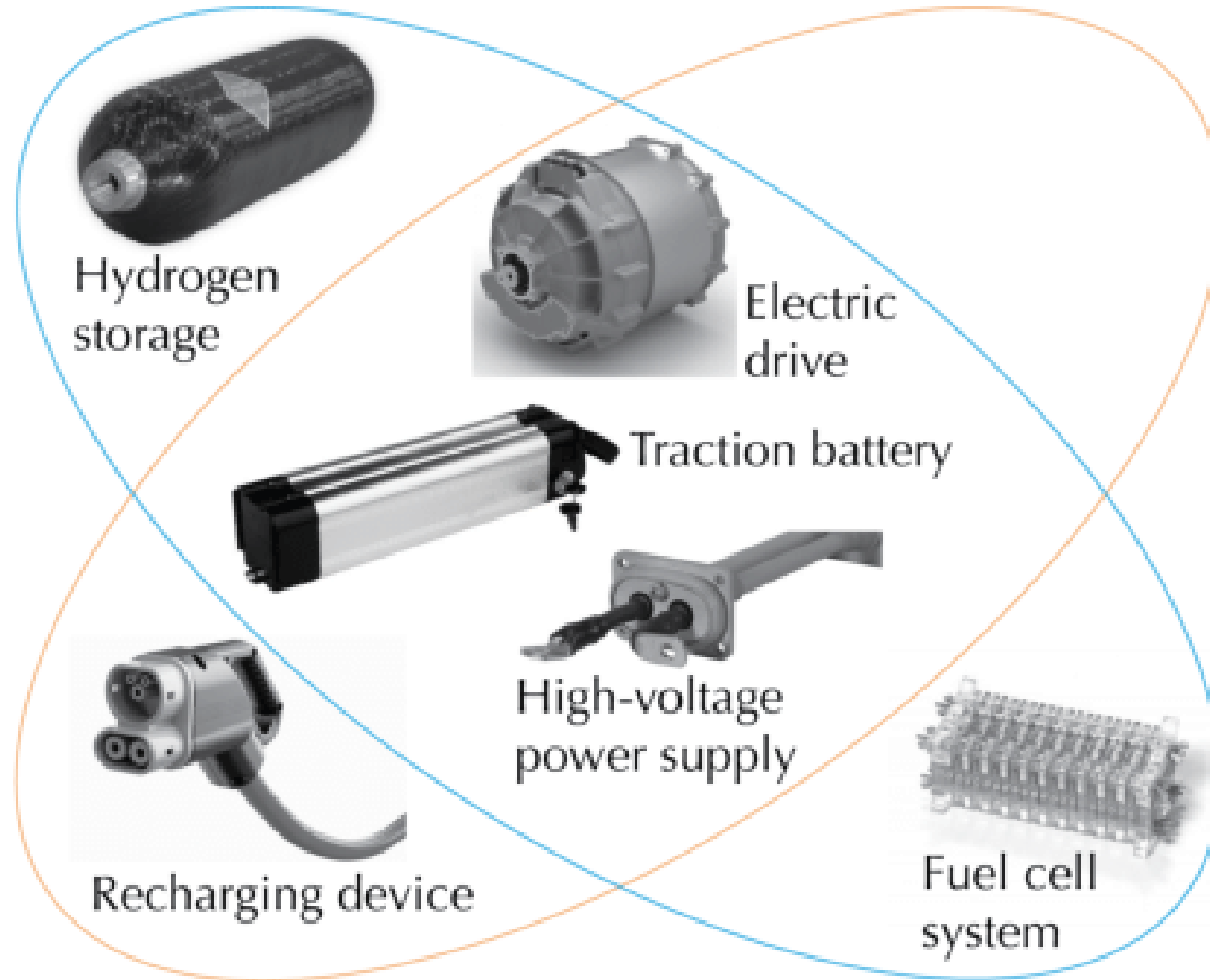


Hydrogen transport



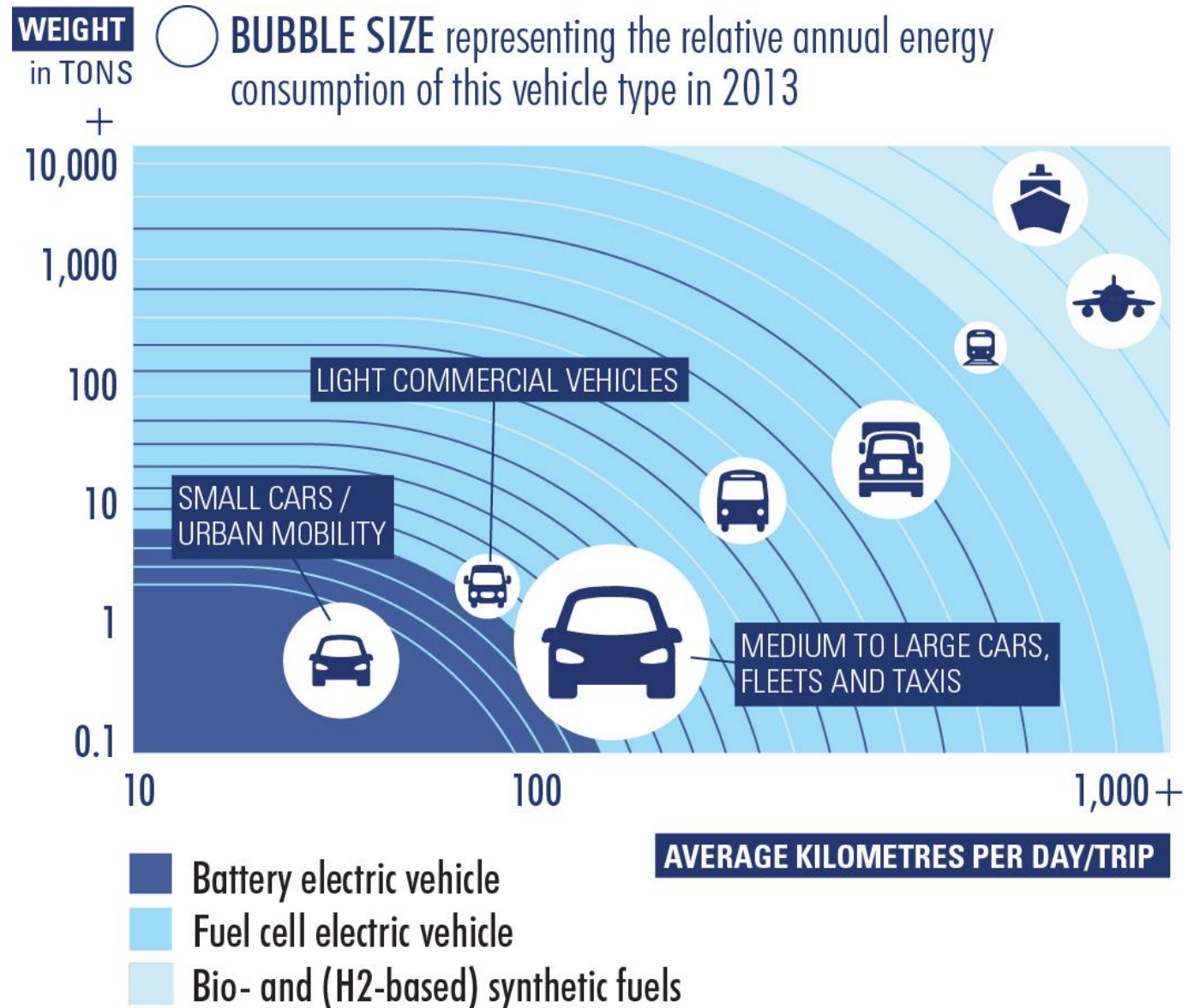
Electricity and Hydrogen are symbiotic

**Fuel Cell
Vehicle**



**Battery-electric
Vehicle**

Propulsion technology types



Hydrogen Refuelling

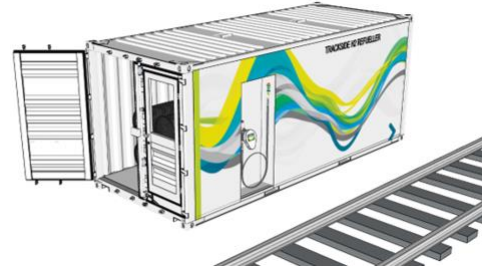


Refuelling Product Spectrum

HySerVE
Mini Hydrogen
Dispenser
50 miles



OLEV Truck
Mobile HRS
60kg storage w
compression



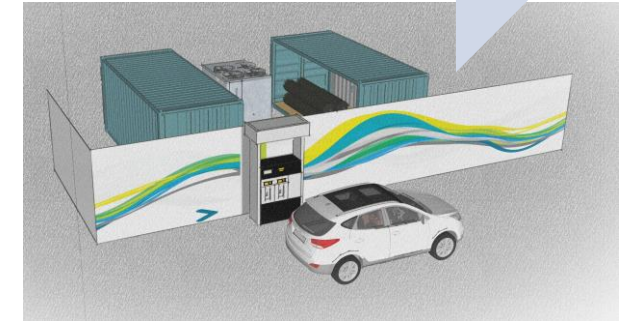
Full Static Station
Hydrogen
producing fully
installed station



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.



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.

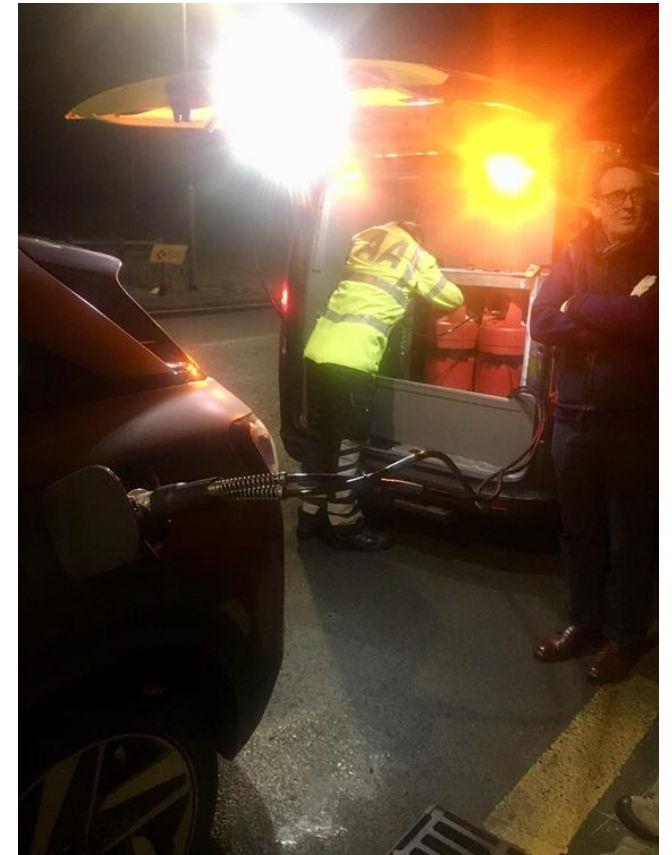


HyFlyer Refuelling

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.



Mini Hydrogen Dispenser



Telegraph Nexo 1000 Mile Trial

The Telegraph

Home > Lifestyle > Cars > Features

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



Save 74





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.



NEWS

Home UK World Business Politics Tech Science Health Family & Education

Business Your Money Market Data Companies Economy

All aboard Britain's first hydrogen train

By Tom Burrige
Transport correspondent, BBC News

🕒 20 June 2019

📌 🗨️ 🐦 ✉️ 🔄 Share



porterbrook 



Hydrogen trains: Are these the eco-friendly trains of the future?

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?



**FUEL CELL
SYSTEMS[®]**

Thank you

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