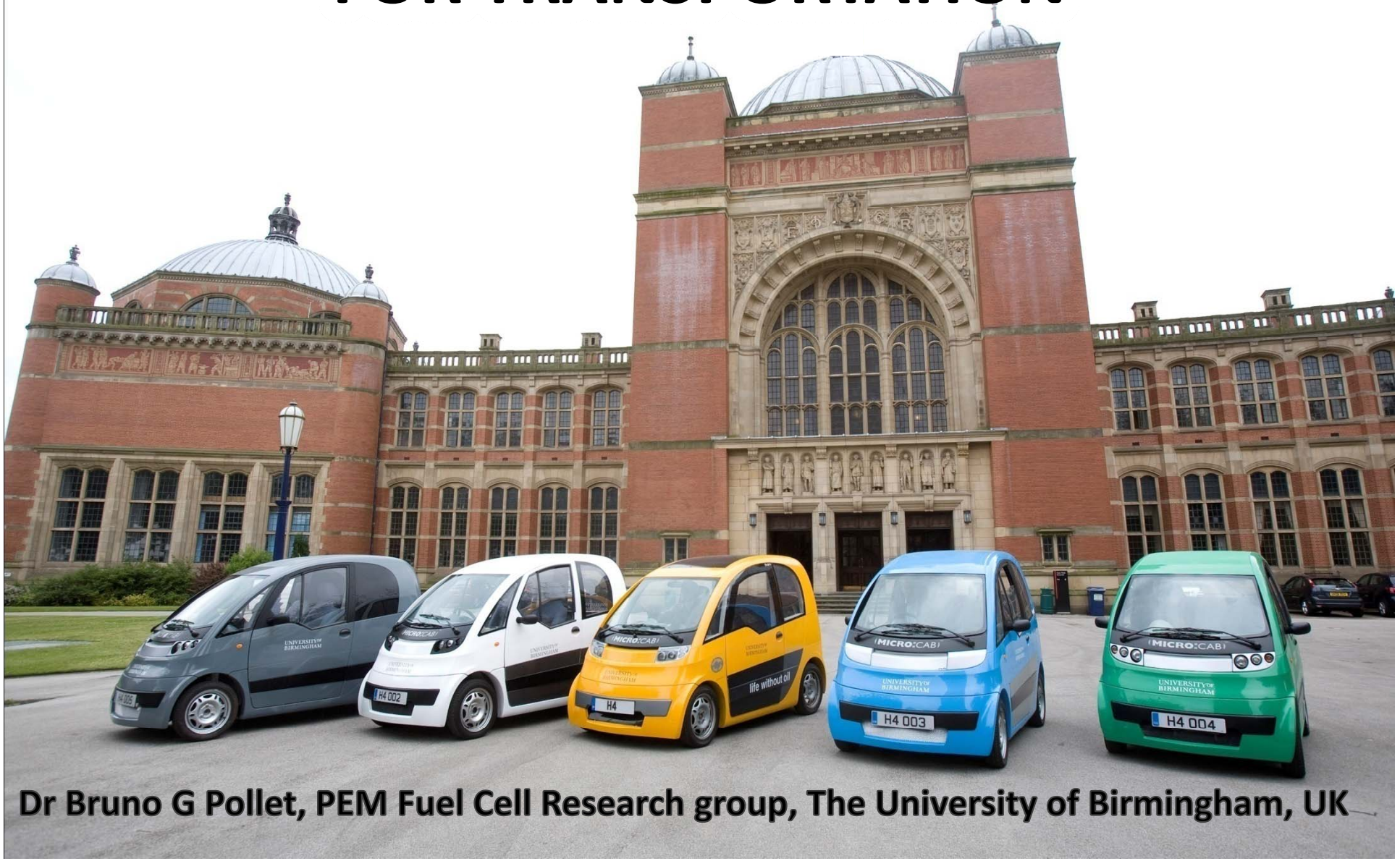
HYDROGEN AND FUEL CELL FOR TRANSPORTATION



Dr Bruno G Pollet, PEM Fuel Cell Research group, The University of Birmingham, UK

Fossil Fuel is Peaking (and it is costing us!)

- 1 bn vehicles now
- 5 bn vehicles in 2050

(due to growing population)

- 2 bn tpa of fuel
- GHGs emission - Around a 1/3 of CO_2 emission originates from transport in the UK (600m tons pa)
- Great need to diversify!!!

- The UK is currently reliant upon 3 main energy vectors (carriers) = Petroleum Products/NG/Electricity

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Emissions Cause Death!

- Approx 8,500 people die in UK as a result of particulate emissions from vehicles

- Every 10 $\mu g/m^3$ particulates ➔ 1% increase mortality (all cause) [Ref - COMEAP Prof Jon Ayres]

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What *Cameron-Clegg* have to say?

➔ *'The UK Government is currently committed to reducing carbon emissions by 80% by 2050'*

➔ *'The UK Government is committed to a substantial increase in renewable energy (from 1.8% to 15%) over the next decade as a major part of its programme to reduce carbon emissions'*

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Energy Density

Amount of Energy stored in a given system per unit Mass

- Pb-acid — 40 Wh/kg
- Li-ion — 180 Wh/kg
- **Fuel cell — 300 Wh/kg**
- **ICEs — 1,000 Wh/kg**

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BATTERY ELECTRIC VEHICLES (BEVs)

Woods Electric
14mph;18miles – Ni-Fe

Milk Float, Smith Delivery Vehicles
75 mph; 65miles – Pb-Acid

Aixam Mega 25mph;
70miles – Li-ion

1997 GM EV1
80 mph; 80miles – Pb-Acid

The Tesla Roadster *The Electric sports car*

Lithium -ion battery
Acceleration = **0 – 60 mph in 3.7 s**
Top speed = **125 mph**
Price = **£90K**

Range = 244 miles (393 km) on a single charge
REALLY????

Jeremy Clarkson pushing the car!

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Mitsubishi iMiEV

- Range: max. **70miles**
- When other ancillary systems on e.g. wipers, headlights, radio etc

➔Range = ca. **30 miles**

- Recharging times – **5 hours** (when battery SOC=70%) & **8 hours** (when battery SOC=10%) – based on 2-phase (i.e. domestic)
- 47 kW electric motor, 58 MJ of battery storage, 1,100kg, £22,000-£27,000
- Efficiency=2.22 $km.MJ^{-1}$ & max. speed=80 mph

Problems with BEVs

- Low Range (up to 100 miles)
- Power drops continually
- Too long to charge up (up to 8 hours)
- Heavy & expensive (**£2K/kWh**) batteries
- Could cause problem with existing grid!

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HYDROGEN *as an Energy Vector!*

produced with NO net CO_2 emissions

- Energy in **1 Gallon of Petrol ≈ 1 kg of Hydrogen**

(= 11,200 litres = 396.5 cubic feet)

- Hydrogen (33,300 Wh/kg) has a very good energy content by weight

≈ 3 X more than **petrol** & **≈ 7 X** more than of **coal**!

➔ **Highest energy content of all fuels on a <u>weight</u> basis**

- Hydrogen has very low Energy content by volume **≈ 4 X** less than petrol

➔ To store 5kg H2 eq. to 5G of petrol, a 5 metre diameter tank would be required!!!!!

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HYDROGEN FUEL CELL VEHICLES (HFCVs)

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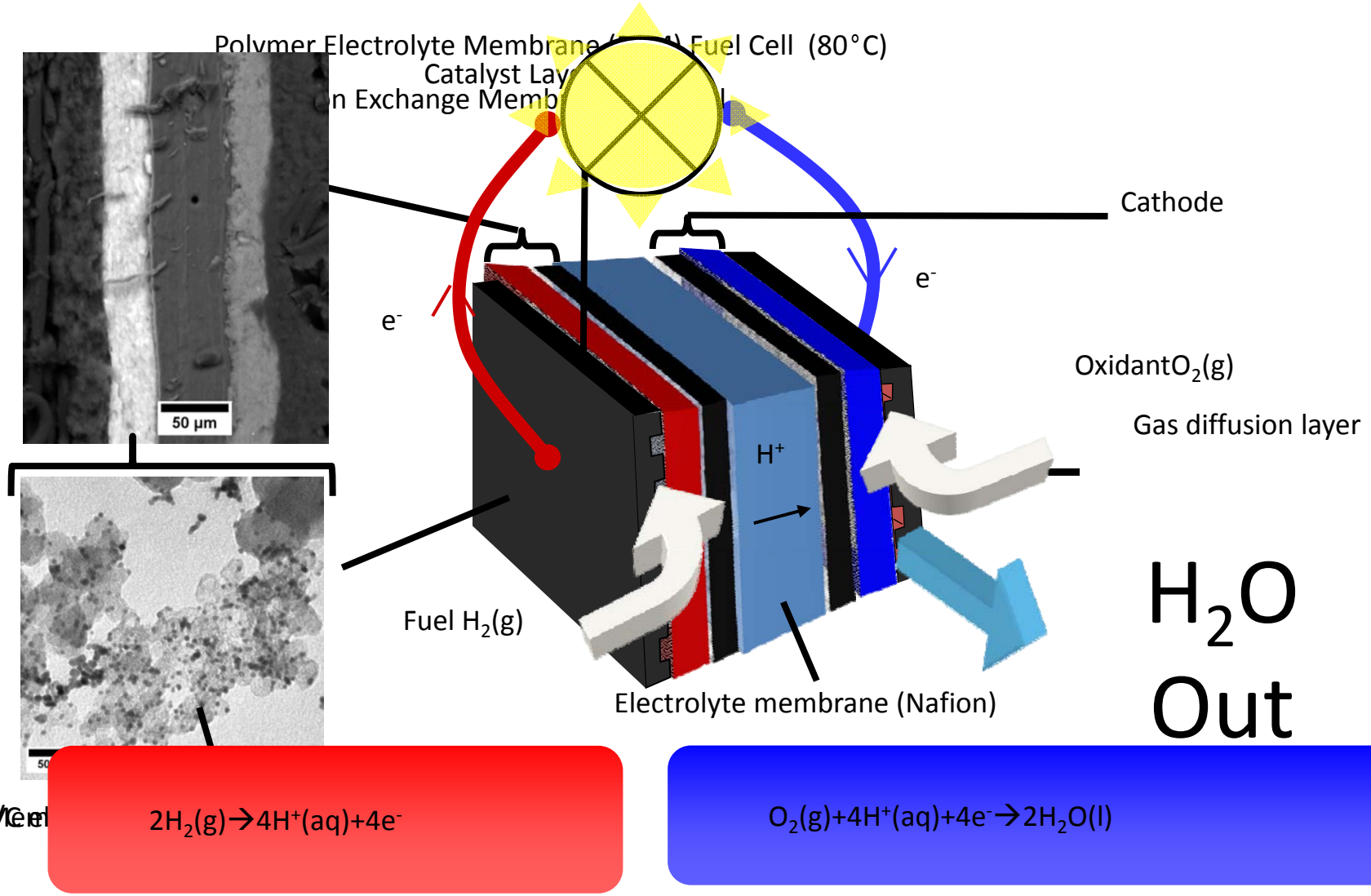
What is a PEMFC?



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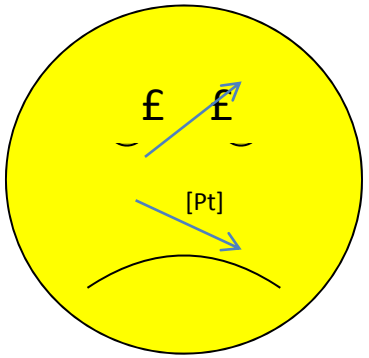
Problems with PEMFC: Cost, cost, cost and availability!



- **Cost – ca. £50/g (03/11)**

For a 100kW PEMFC stack; 30g-60g of Pt = **£1,500-£3,000**!!!!

➔ Price of a stack = **£4-5K/kW**

➔Objectives: decreasing Pt loading by 4-10 fold

➔If 600m HFCVs (100kW), **20,000-40,000** tons of Pt required

- **Availability ➔ Scarcity**
  - Worldwide Pt reserves ~ 30,000-100,000 tons
  - Annual production rate ~ 30 tons / year
  - Commodity market: supply & demand

Source: "Platinum availability and economics for PEMFC commercialisation", TIAX LLC report to US DOE, 2003

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Problems with HFCVs!

- **Currently too expensive** (£50K-£1m)
- **Needs pure Hydrogen** (99.999%)
- **Durability** (5,000 hours max.)

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HYDROGEN FUEL CELL HYBRID VEHICLE (HFCHV)

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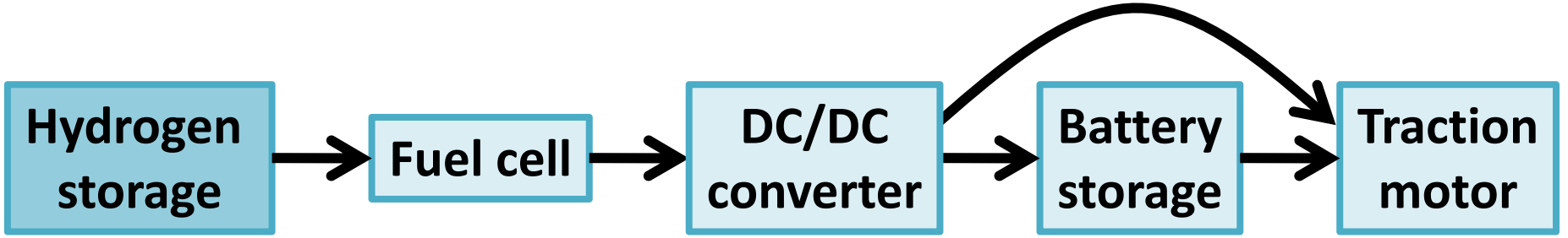
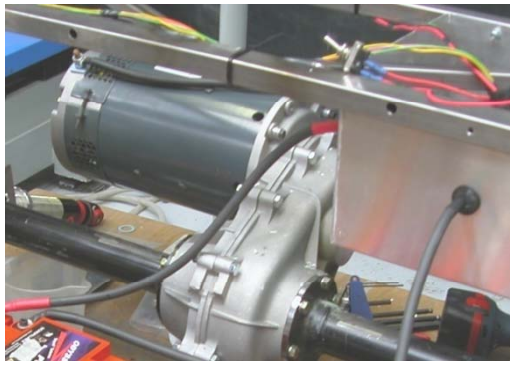
The *guts* of a HFCHV

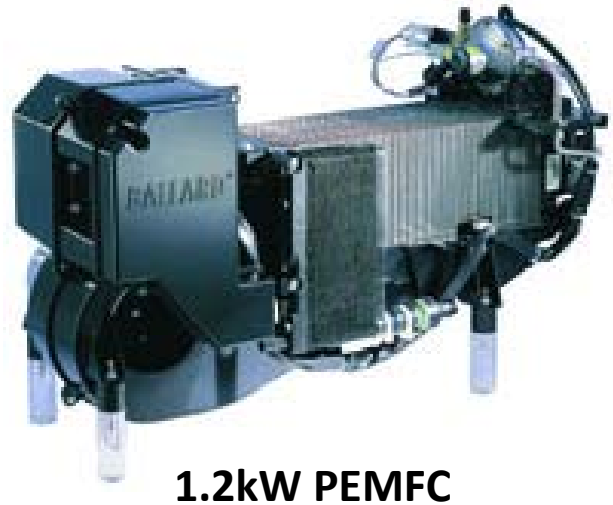


Hydrogen pressurized tank

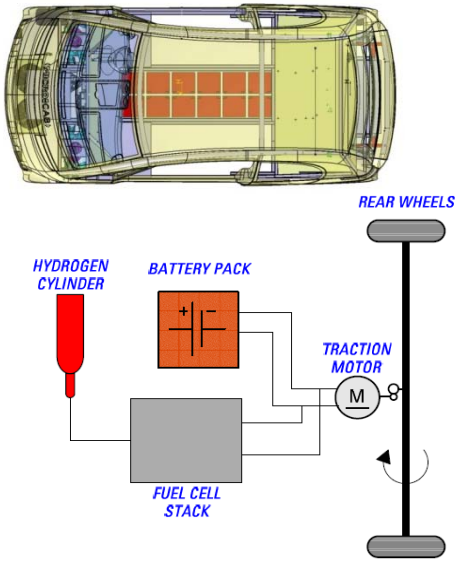
1.5 kWh Pb acid battery pack

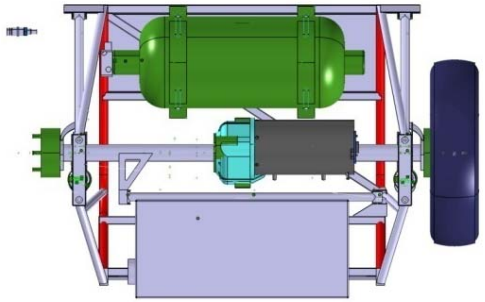


4 kW (9 kW PP) Electric motor with gear box



1.2kW PEMFC





Demonstration at UoB

- Top speed = **26.9 mph in 25s**
- Acceleration = **1.5 m.s^{-2}**
- Vehicle Range = 115 km = **71 miles** (full throttle)
- Refuelling time = **3 minutes**!
- Present fuel cost **20p/mile** (diesel £1.40 per litre = 10-25p/mile)
- Overall energy efficiency **1 km/MJ** BETTER than diesel **0.3 km/MJ**
- **77 mpg** -diesel equivalent
- Combined **3,000km** travelled
  (approx. 3,000 trips around campus)
- Racked up **5,000 hours** operational time
  (>2,000 in the leading vehicle)
- Over **120** refuelling events
  (58kg of hydrogen transferred with no incidents)

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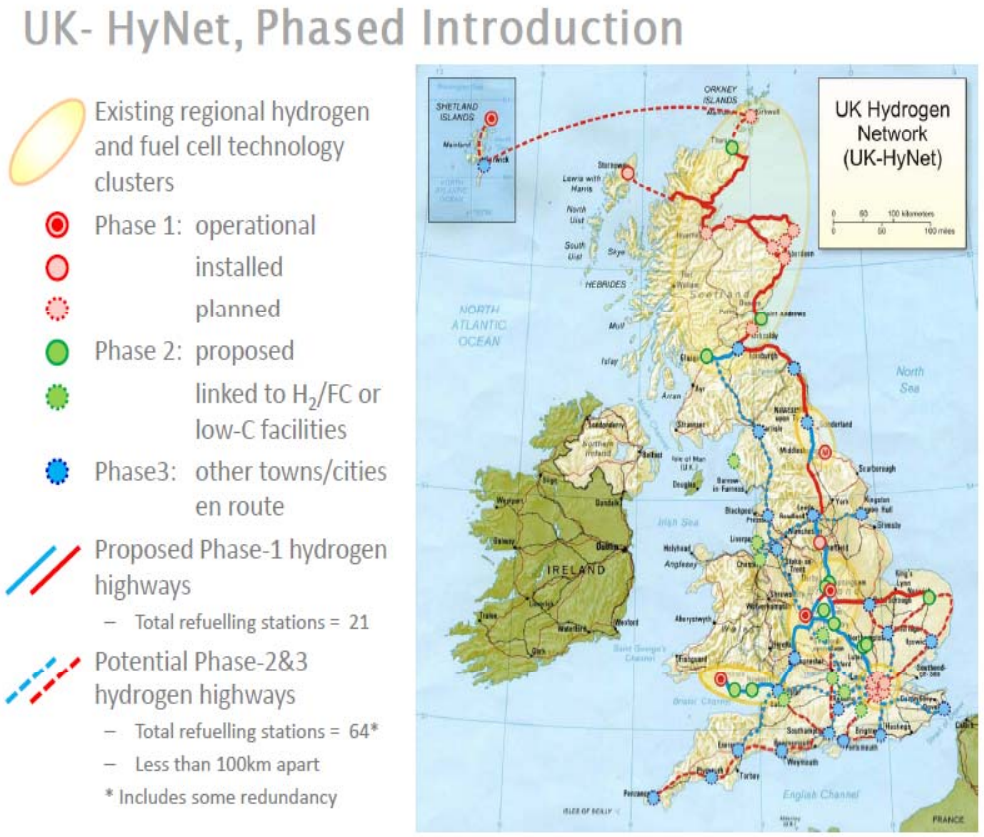
Hydrogen Infrastructure

• In Europe, if 40 millions H_2 cars on the road by 2030 ➔ 19,000 hydrogen fuelling stations, costing **€6b – €24b** comparable to mobile phone and broadband infrastructure!!!!

Hydrogen Refueling Station, UoB



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BENEFITS to West Midlands and the UK

- New infrastructure & facilities
- SMEs & new companies
- Job creation
- Training of personnel (acquiring new skills)
- Local wealth

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HFCHV

Video

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Hydrogen Fuel Cell Supply Chain (ca. 60 SMEs)

Adelan Ltd

IPS
ENABLING THE ENVIRONMENTAL ECONOMY

H C L

THE HAMPTON WORKS (Stampings) Ltd.

ASCO JOUCOMATIC numatics
EMERSON Industrial Automation

biowaste 2energy

Rondol

tempus

mbes

wrk
DESIGN & SERVICES LTD
Consulting Chemical Engineers

H2 Renew
A RENEWABLE ENERGY COMPANY

Bac2
Conductive Composites

Energized

RDM AUTOMOTIVE
COMPONENTS AND SERVICES

PROTO SYSTEMS LTD

GTM

simpact

Bailey & Mackey Ltd

KATRONIC

EF EUROFRIGO
TRANSPORT REFRIGERATION & AIR CONDITIONING

JM Johnson Matthey Fuel Cells
the power within

MICRO:CAB™

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Need for Novel Technologies & IP in HFC in our Region!

Video

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Conclusions

- BEVs need to be further improved for long distances
- Li-ion batteries & FC systems are expensive
- Battery weight & charging times are major problems
- HFCHVs looks good!!!
- HFCHVs ideal for fleet operators and longer journeys
- **BUT** need to have a Hydrogen infrastructure
- Moving away from ‘brown’ H2 to ‘green’ H2

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Final thought…

Can I drive to Scotland from Coventry with my HFCHV without having this range anxiety and a panic attack?

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Thank you for listening!

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- RCUK

www.fuelcells.bham.ac.uk www.polletresearch.com

www.microcab.co.uk

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