Supply Chain Research Applied to Clean Hydrogen (SCRATCH)

EPSRC

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University of Birmingham

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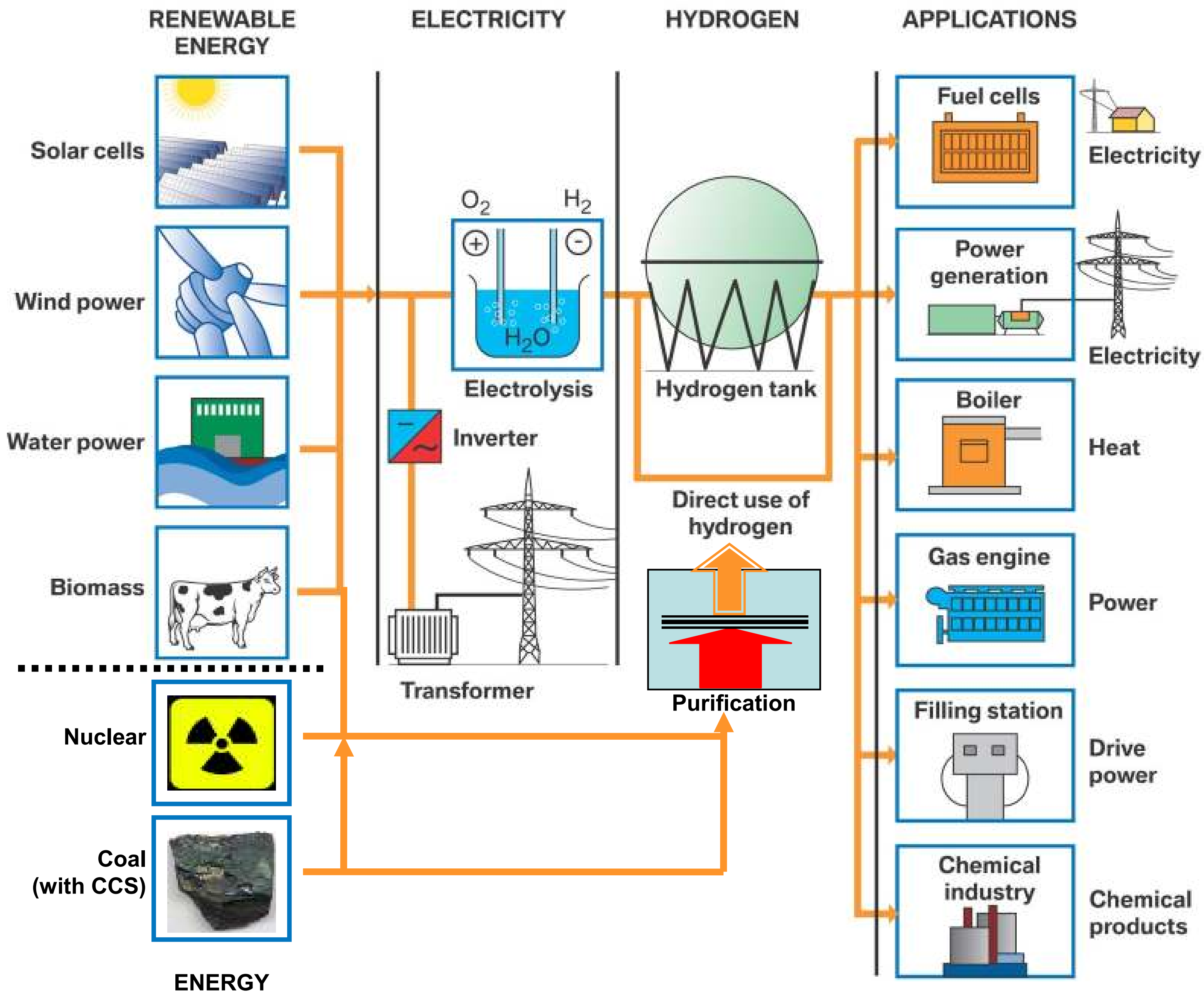
Hydrogen Production & Use



Capital

Proposal submitted to AWM in 2005; initial decision on funding in May 2006 (final June 2007)

AWM **"Fuel Cell Technology Supply Chain" - £0.5M**
Started June 2007

Outputs:

- 30 business assists
- 30 collaborations between SMEs and knowledge base
- Training support for 30 individuals, including SME installers and students

Deliverables:

- Refurbished space and laboratory with state of the art equipment for testing fuel cells
- Final report

Project completion in 36 mths
Outcomes followed up to 5 yrs

Revenue

Proposal submitted to EPSRC in August 2006; decision on funding in March 2007

EPSRC **"SCRATCH"** - Supply Chain Research Applied to Clean Hydrogen - **£1.2M**
Started May 2007

Manpower:

- 5 Scientists and 1 technician to carry out delivering on **FCTSC**

Tasks:

- Bio-mass hydrogen production
- Hydrogen storage and infrastructure
- Hydrogen, fuel cells and CHP
- Economic barriers to hydrogen supply chain **(IERP)**

Deliverables:

- Scientific papers, conference proceedings, dissemination
- Final report

Capital

Proposal submitted to AWM in August 2006; decision on funding in December 2006

AWM Science City UB - Warwick Universities **"Hydrogen Energy" £6.29M**
Started December 2006

Outputs:

- Increase profile of region and universities in H_2 Energy
- Job creation – 11
- Job safeguarded – 16
- Business support – 15
- Business engaged with the knowledge base – 15
- Skills – people assisted to improve skills – 30

Delivery over 5 years period i.e. by December 2011

DBERR-Hydrogen Fuel Cell Vehicle Demonstration Project - **£1.3M**
Started April 2008

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Created by: Dr W. Bujalski

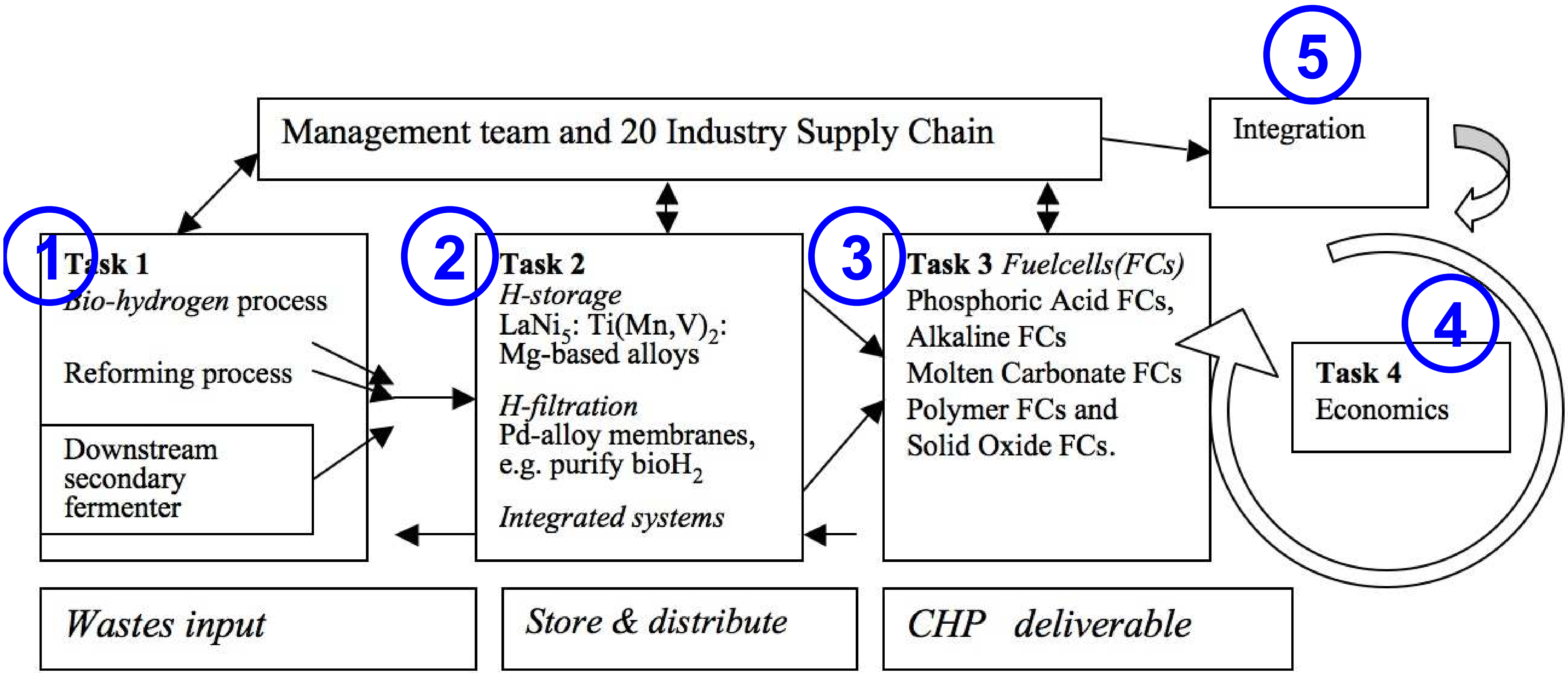
Supply Chain Research Applied to Clean Hydrogen (SCRATCH)

- The hydrogen economy is gradually emerging but the supply chain of companies producing hydrogen, distributing it, utilising and marketing it has not yet been established.

- Hydrogen mini-economies exist on petrochemical sites, and the objective of this project is to spread these more generally across the country, starting with Birmingham Univ. campus.

- This project will focus on 20 companies which produce components for the hydrogen economy, which is viewed as three linked technologies:
  - -hydrogen from biomass;
  - -hydrogen distribution and storage; and
  - -hydrogen utilisation by fuel cell chp.

- The project will produce new research results to facilitate the H_2 economy, overcoming economic & technical barriers.



Duration: May 2007 - May 2011

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How we produce Hydrogen

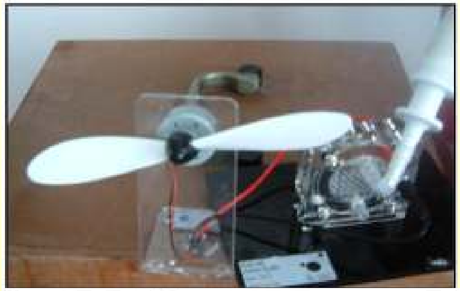
- **Biohydrogen: Food wastes + bacteria ⟹ H_2 (bioreactors)**
- **Supercritical Water Gasification** (SWG): Dissolution of organic compounds & lignocellulosic materials, as solid biomass in SC water at elevated temperature gives H_2
- **Electrolysis**: Water ⟹ $H_2 + O_2$
- Hydrocarbon (Reforming)
- Photo-electrochemical Water Splitting

1 Bio-Hydrogen

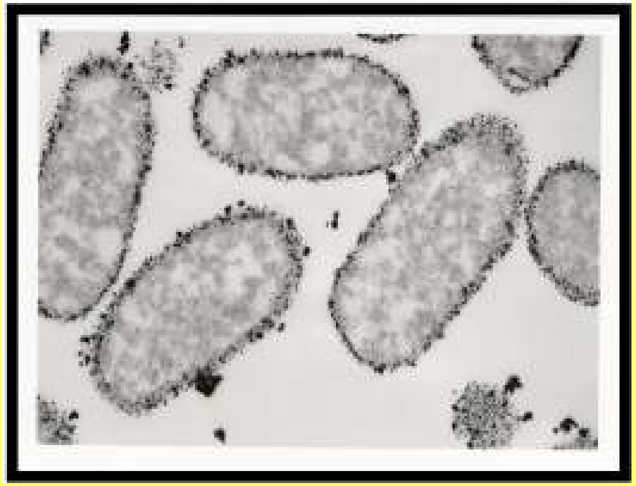
HYDROGEN

Biosciences Research

Hydrogen from biodegradable waste *by fermentation*



Generation of electricity by a fuel cell



Use of bacteria to produce palladium catalyst

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① Bio-Hydrogen

- Long-term collaboration with industrial partners EKB Technology and C-Tech Innovation contributed to the generation of IPR to protect a process for the efficient production of biohydrogen from organic wastes.

- The process combines dark fermentation and photofermentation to maximise the potential for hydrogen production.

- Proof of concept studies, were followed by the formation of Biowaste2energy Ltd in January 2008, and development work is underway to bring the technology to market.

biowaste 2energy

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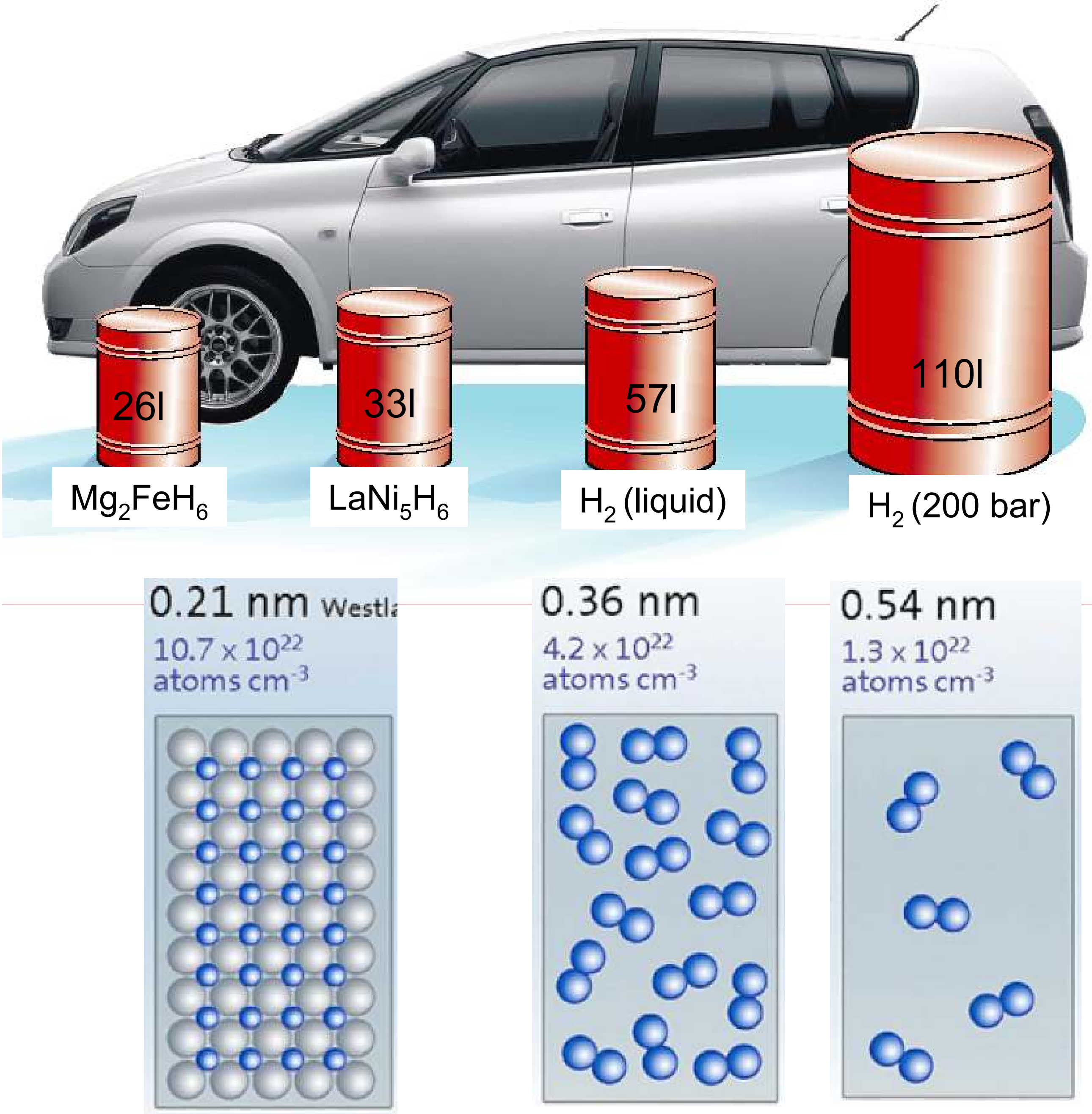
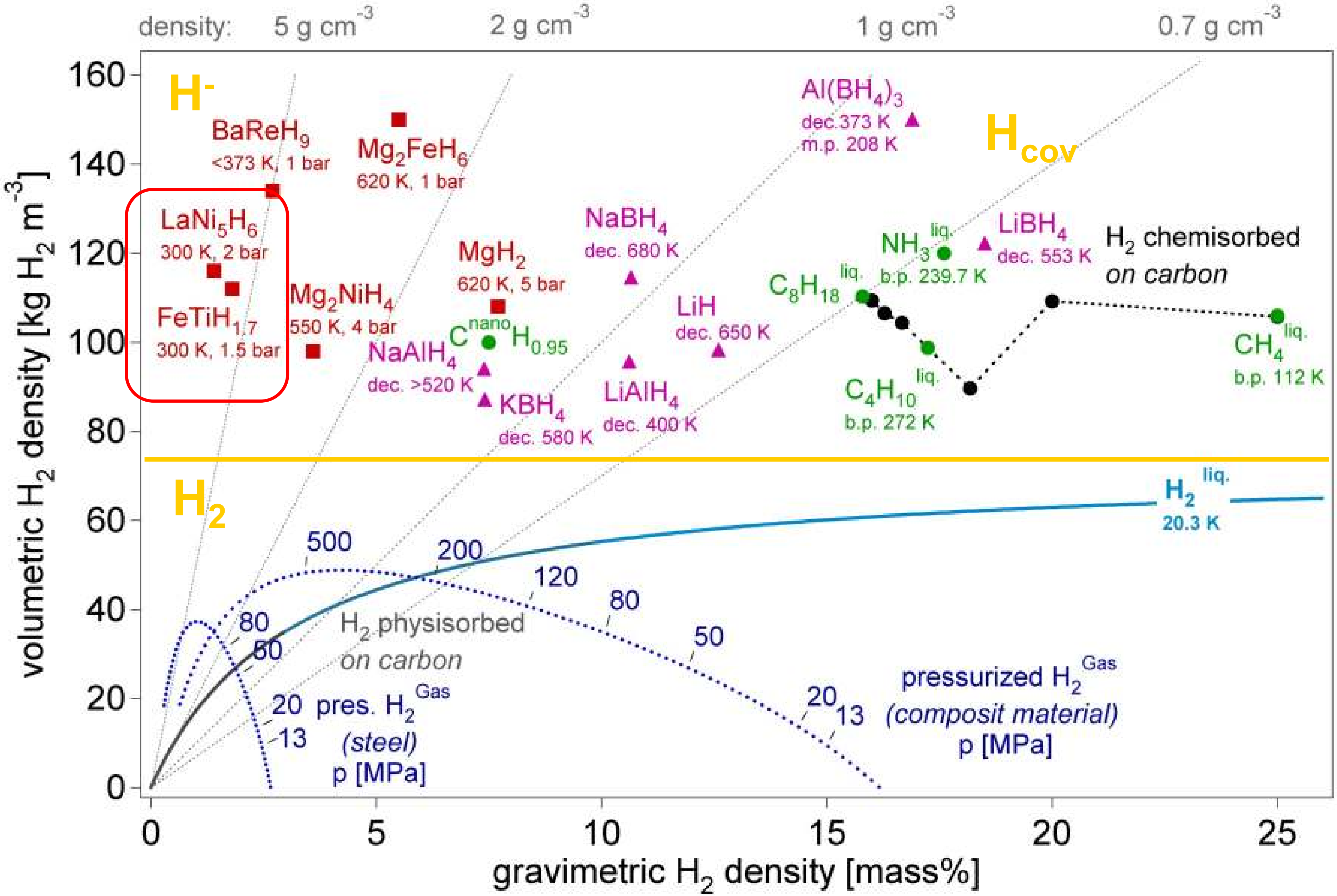
2i Hydrogen Storage

4 kg hydrogen

Louis Schlapbach &
Andreas Züttel,
NATURE, 414, p.353,
(2001)



2i Hydrogen Storage



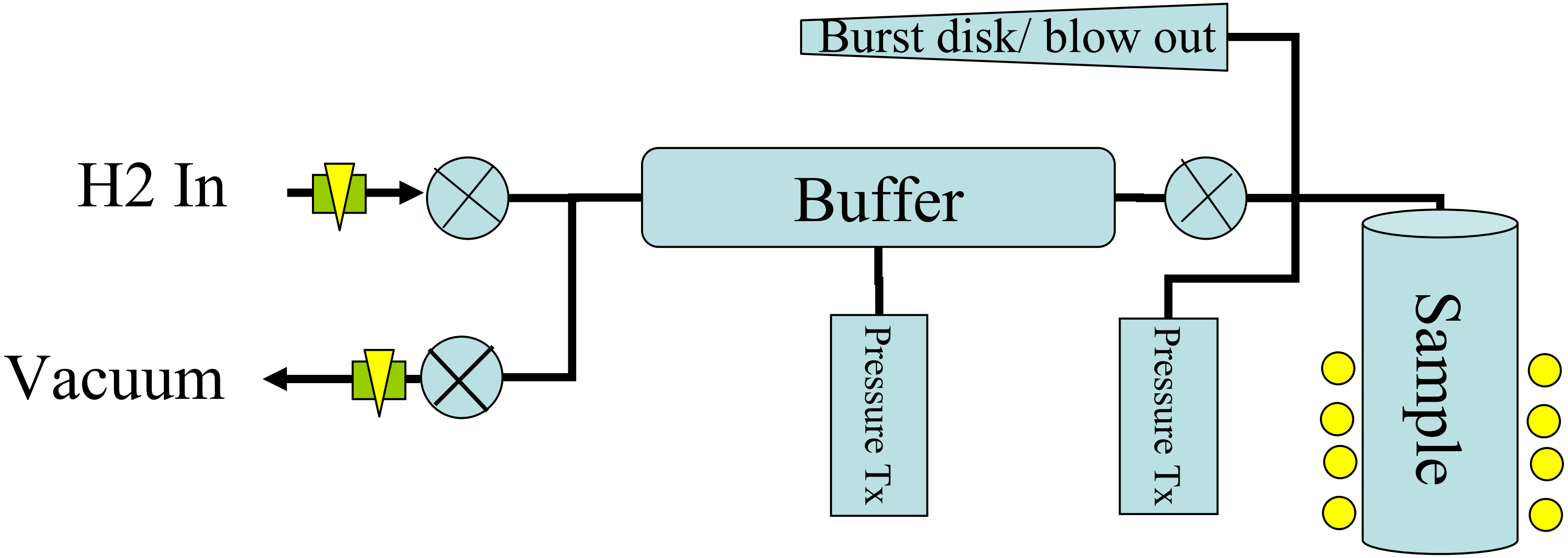
Ref: A. Züttel, "Materials for hydrogen storage", materialstoday, Septemper (2003), pp. 18-27

Requirements for Hydrogen Stores

- High H content per unit:
  - mass and volume of material (for mobile)
  - volume of material (for stationary and marine)
- Low cost
- Absorb & Desorb H_2 near 1 atm and RT
- Reproducible & favourable reaction kinetics
- Not readily poisoned by gaseous impurities
- Safe on exposure to air

2i Hydrogen Storage

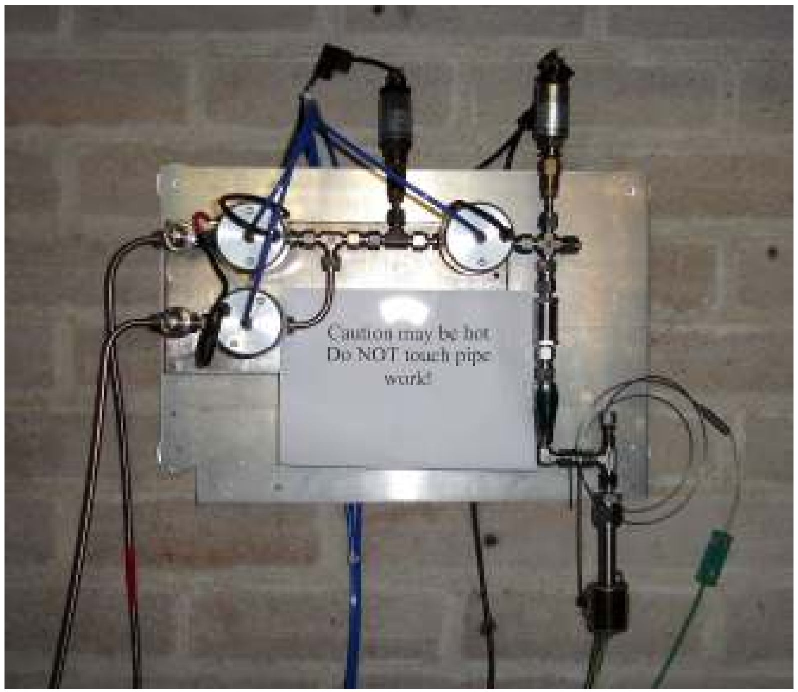
Store cycling system: Pressure cycling



Designed with computer controlled valves for cycling, data logging of temperature and pressure.

These multiple pressure transducers will allow for pressure control and act as a PCT measurement system

Look at effect of impurity gases

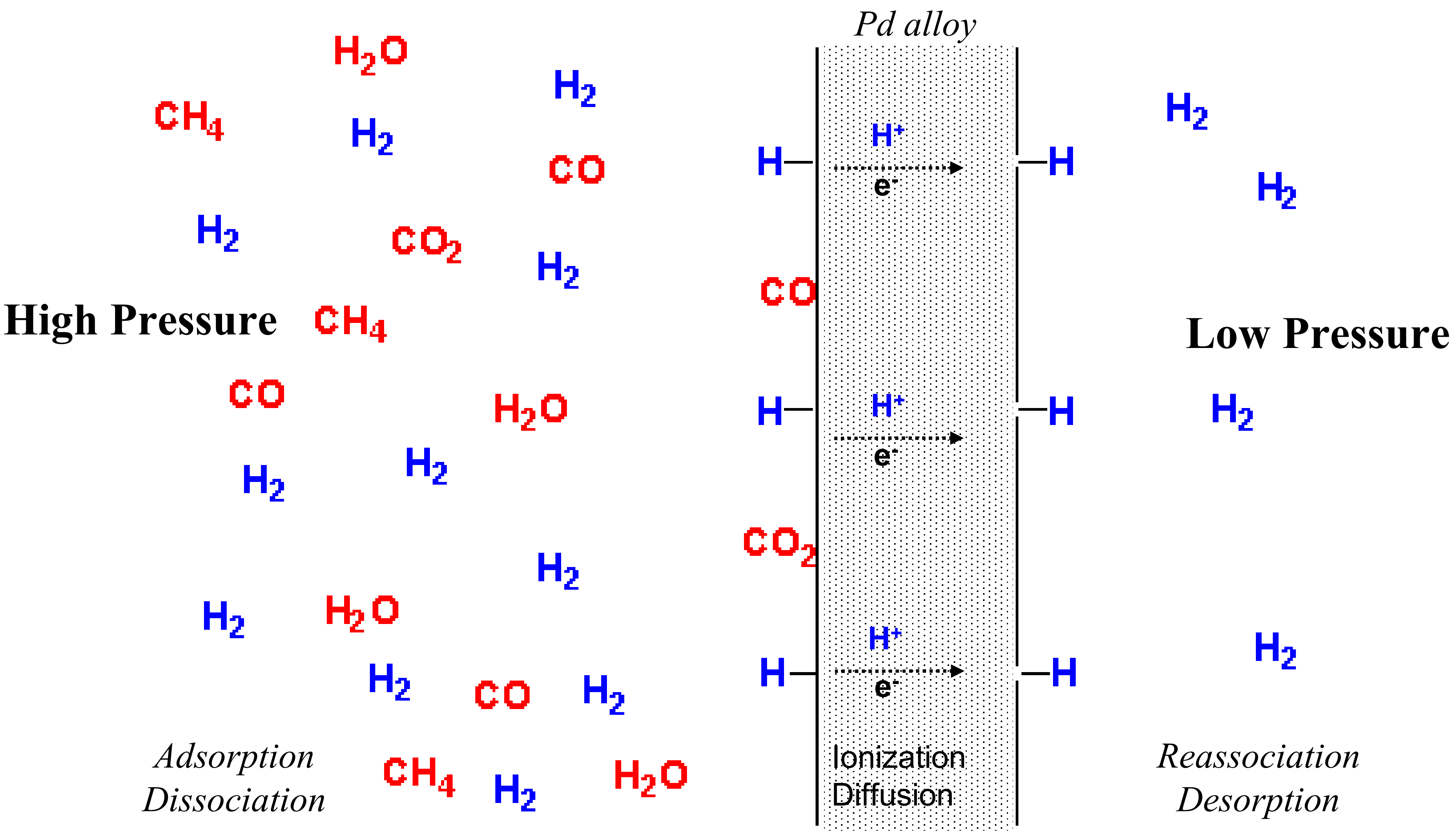


The Need for Pure Hydrogen

- PEM Fuel Cells are poisioned by: CO > 10ppm, and Sulphur at ~ 1ppb
- Hydrogen needs to be separated from mixed gas streams: synthesis gas from natural gas, coal, or biomass
- Current technology is geared to large-scale: Water-gas-shift reactors, followed by pressure-swing adsorption (PSA)
- Hydrogen Separation Membrane advantages:
    - Lower capital costs
    - Smaller physical space requirements
    - Fewer moving parts
    - Improved thermal efficiency (don't need to cool and reheat gases)
    - Potential to intergrate membranes, with H_2 production systems.

② ii Hydrogen Purification

Metallic Membrane H_2 Purification



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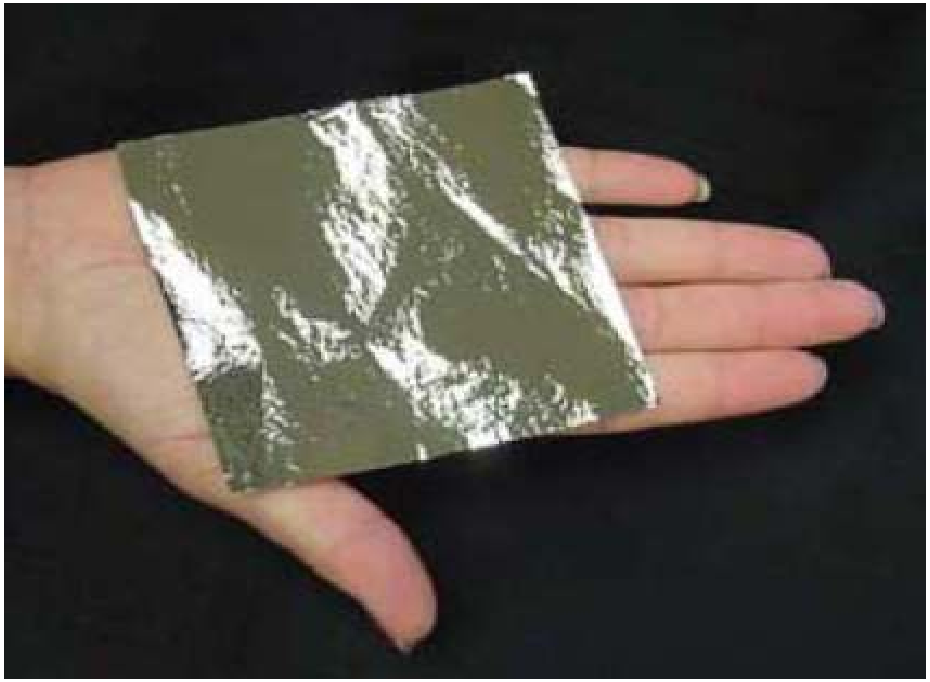
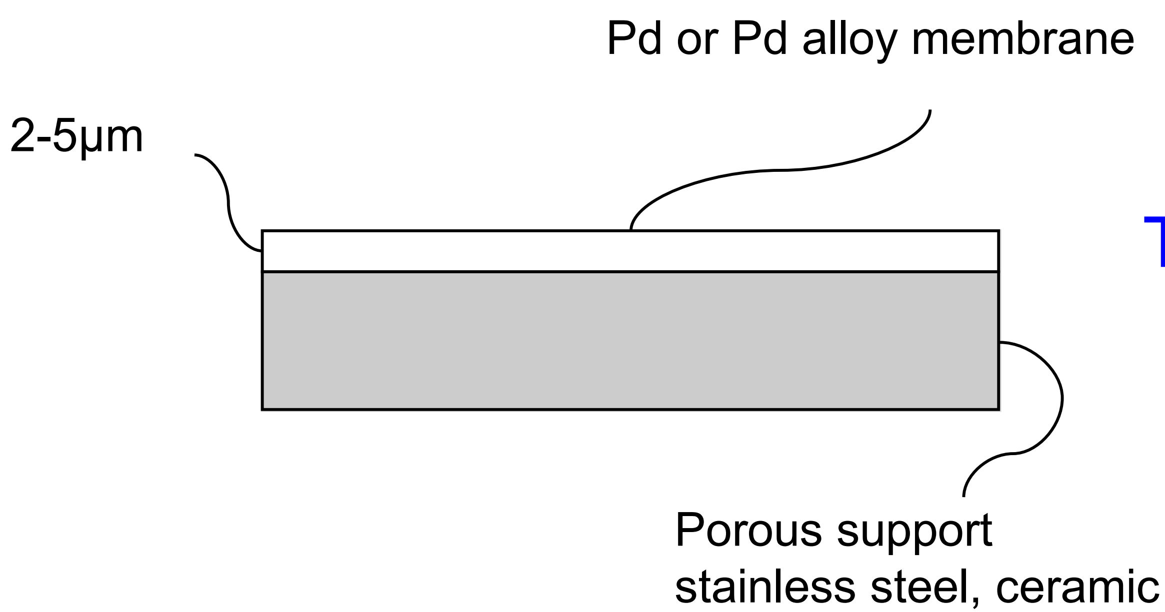
2ii Hydrogen Purification



Rolled Palladium Alloys
~ 25 µm thick.



Thin-film Pd Alloys

Fuel Cells Technologies

Fuel Cell Type	Electrolyte	Anode Gas	Cathode Gas	Temp.	Eff.
Proton Exchange Membrane (PEM)	solid polymer membrane	hydrogen	pure or atmospheric oxygen	75°C (180°F)	35 – 60%
Alkaline (AFC)	potassium hydroxide	hydrogen	pure oxygen	below 80°C	50 – 70%
Direct Methanol (DMFC)	solid polymer membrane	methanol solution in water	atmospheric oxygen	75°C (180°F)	35 – 40%
Phosphoric Acid (PAFC)	Phosphorous	hydrogen	atmospheric oxygen	210°C (400°F)	35 – 50%
Molten Carbonate (MCFC)	Alkali-Carbonates	hydrogen, methane	atmospheric oxygen	650°C (1200°F)	40 – 55%
Solid Oxide (SOFC)	Ceramic Oxide	hydrogen, methane	atmospheric oxygen	700–1000°C (1300–1800°F)	45 – 60%

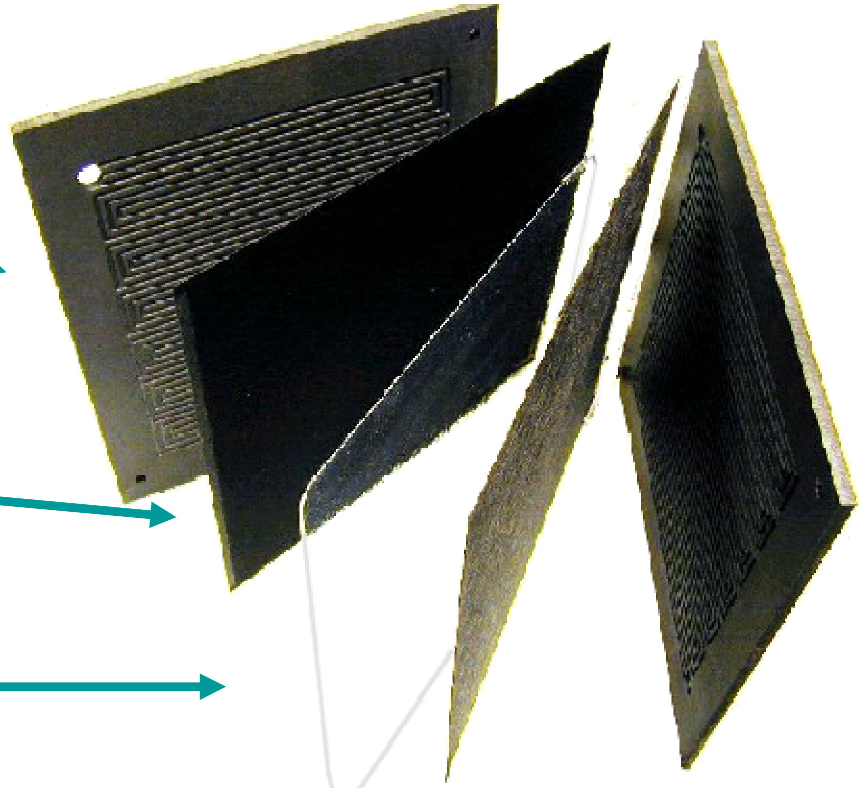
3 **Fuel Cells**

Our Key Research Areas

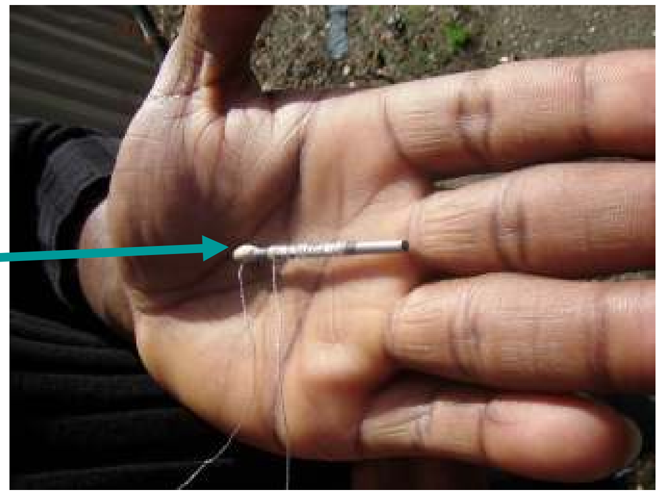
Flow Field Plate

Gas diffusion layer
and catalyst layer

Proton Exchange
Membrane



Microtubular SOFC



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Key Research Areas (1/2)

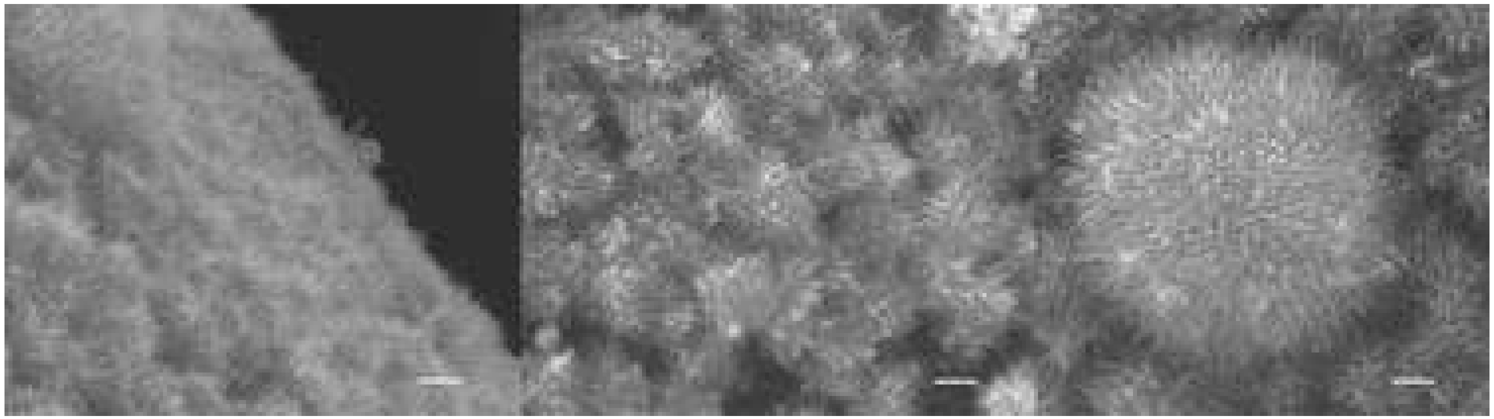
- Novel low cost materials with high performance & longevity for: bipolar plates (BPPs), current collector plates (CCPs), gas diffusion layers (GDLs), catalyst layers (CLs) and solid electrolyte membrane (polymeric & ceramics)
- Novel low cost fabrication processes for such materials
- New development of test methods (ex-situ & in-situ diagnostic) for determining physical properties, performance & durability of PEMFC & SOFC
- Improving electrocatalysts & noble base metal alloys, catalyst utilisation and electrode design
- Developing & testing non-noble metal electrocatalysts in views of reducing cost while improving on performance and durability

Key Research Areas (2/2)

Developing & testing novel type of electrocatalysts and noble base metal alloys as Nanoparticles

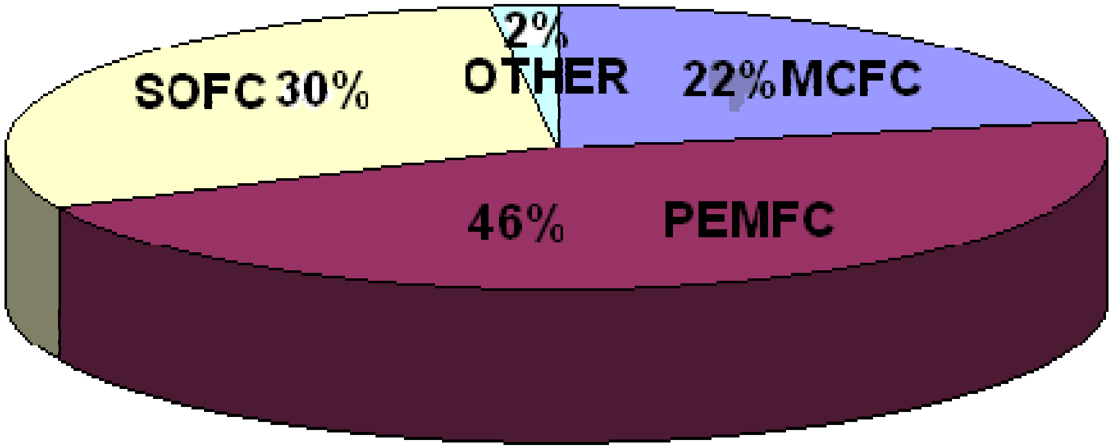
New catalysts are needed in practical applications to improve the performance and reduce the costs of fuel cells. By understanding the basic science of nanoparticle catalysts, novel fuel cell MEAs will be produced and tested in engineering applications.

The research is based on designing and preparing the electrocatalytic materials by the colloidal technique.



Scale 100nm

Market Forecasts



Revenues by Technology Forecast (2010) for Fuel Cells Market in Europe

The overall fuel cell market is segmented on the basis of the power output categories into three different markets:

< 50 kW – PEMFC/SOFC/AFC/DMFC for portable & micro/mini CHP systems

50 kW - 300 kW – MCFC/SOFC for residential & commercial – PEMFC for transportation

> 300 kW – MCFC/SOFC larger CHP systems

UK West Midlands H_2&FC Suppliers

Adelan Ltd

Alkene = Fuel Cell

biowaste 2energy

Rondol

wrk DESIGN & SERVICES LTD
Consulting Chemical Engineers

H2 Renew
A RENEWABLE ENERGY COMPANY

Bailey & Mackey Ltd

KATRONIC

HCL

GTM

THE HAMPTON WORKS (Stampings) Ltd.

ASCO JOUCOMATIC numatics
EMERSON. Industrial Automation

tempus

mbes

Energized

Alkene = Chemical Solutions
...Helping SMEs Succeed!

RDM AUTOMOTIVE COMPONENTS AND SERVICES

simpact

EF EUROFRIGO TRANSPORT REFRIGERATION & AIR CONDITIONING

MICRO:CAB™

FRIDGE XPRESS
DELIVERING QUALITY FRIDGE VANS FAST

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• Hydrogen and Fuel Cell Supply Chain Workshop was held on Wednesday 28th November 2007

• Allowed SMEs to gain new understanding of hydrogen energy technology and to meet University researchers

• Over 60 people attended this workshop.

Two major requirements

If we are to establish a supply chain:

- It must be technically feasible
- The people involved must expect to make money
  - Is it going to make money?
  - When is it going to make money?
  - What is stopping it from making money?
  - Would this technology be profitable if prices reflected all the social costs and benefits involved in it?

Externalities

- An externality is a way in which someone else is affected by something that you do, without a market transaction being involved

- In the presence of externalities, the market will tend to give "the wrong result"

What externalities?

- Pollution from electricity generation

(Sulphur dioxide, Nitrogen oxides, Carbon dioxide)

- Need to coordinate generation with demand for electricity

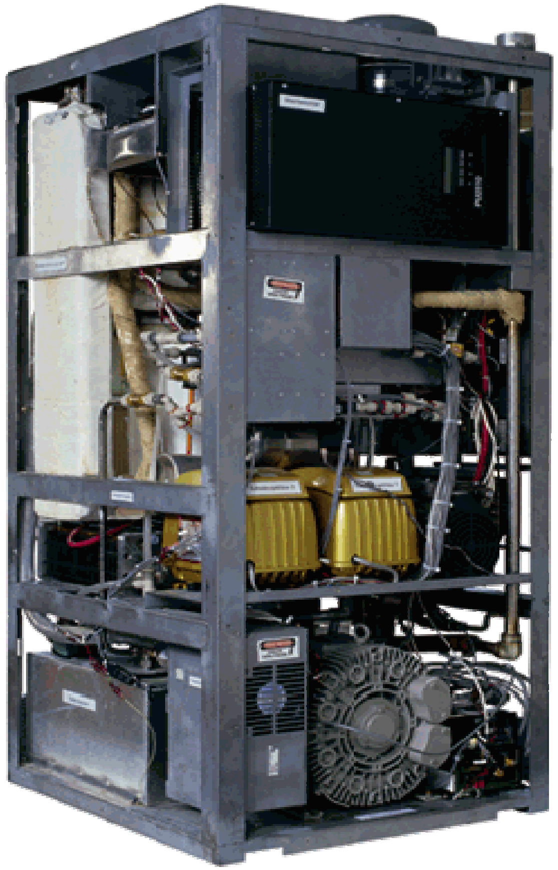
(or else…)

Objectives for this work

- Identify the real externalities
- Quantify them!
- Assess policies that take account of them
- Predict what is needed for the supply chain to become profitable

Successful Projects

Combined Heat and Power
System for domestic applications



Example of successful project using Hydrogen Fuel Cell for household applications

5 Integration

House in the West Midlands heated by a Hydrogen Fuel Cell

Fuel:
Natural Gas & Air

The fuel cell has a dual purpose:

(i) Supply of electricity
(ii) Heating

BLACK COUNTRY HOUSING GROUP
Housing and community solutions

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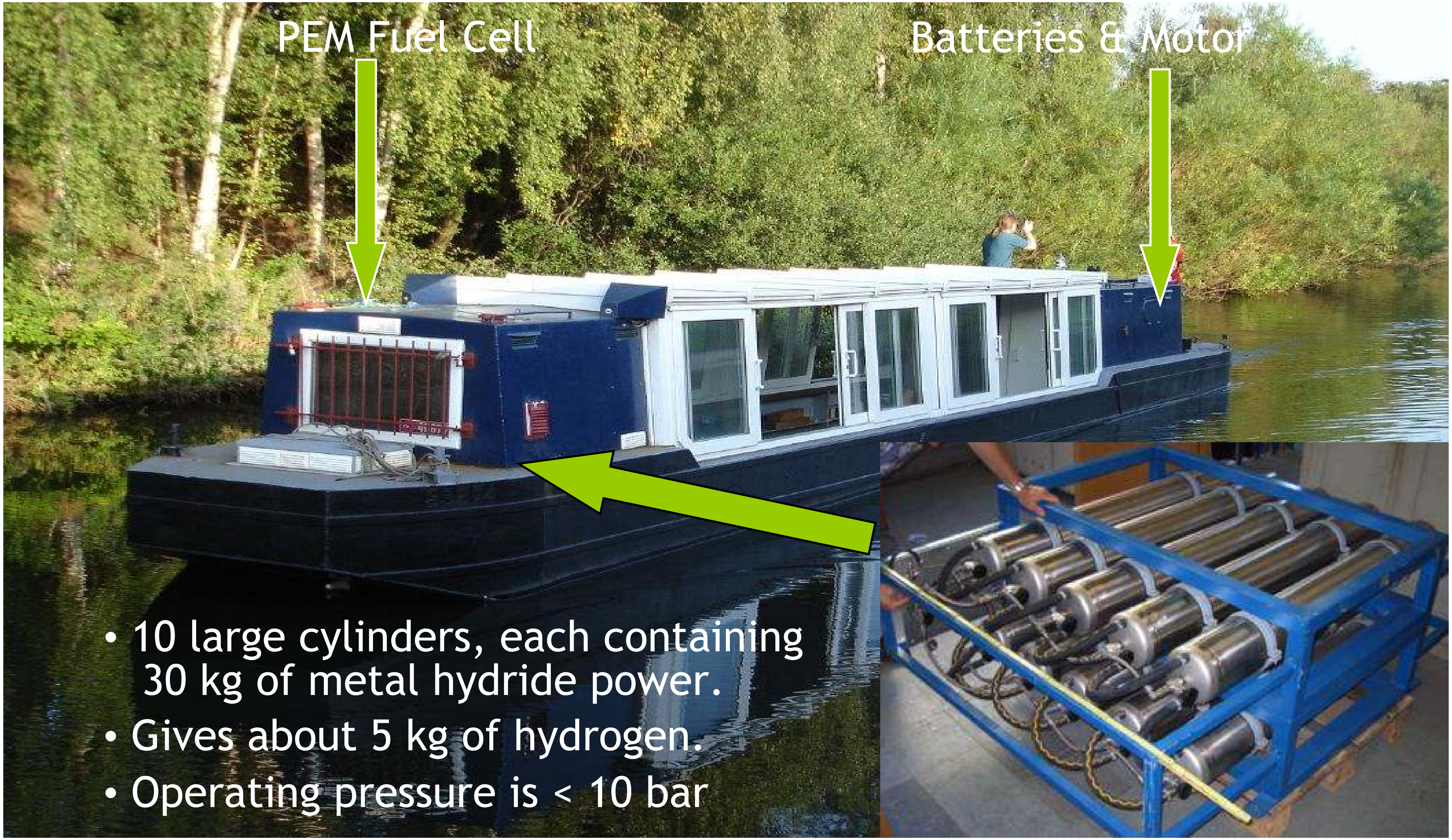
5 Integration

Hydrogen Fuel Cell Narrow Boat



- 10 large cylinders, each containing 30 kg of metal hydride power.
- Gives about 5 kg of hydrogen.
- Operating pressure is < 10 bar

www.hydrogen.bham.ac.uk/protium.htm

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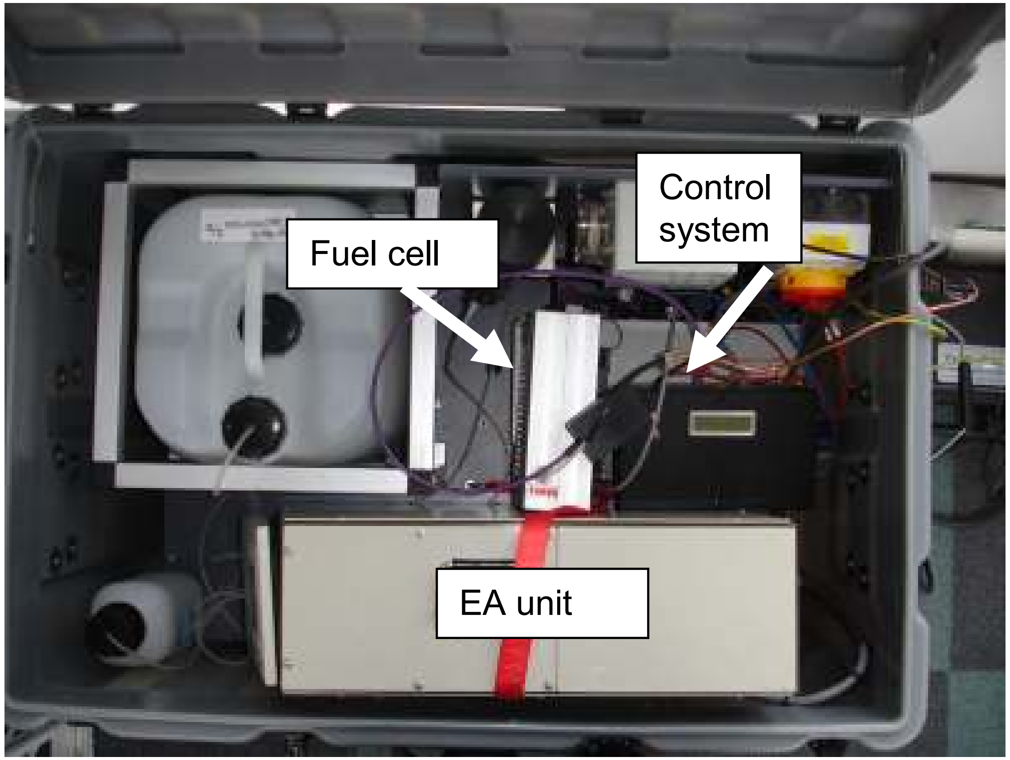
5 Integration

Environment Agency Project

To supply remote power (for remote water quality measurement) via a fuel cell and metal hydride store and extend the operational runtime from 1 day on batteries to 7 days in a hybrid form



The project has passed lab based trials and is heading outside for field trials

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⑤ Integration

Valeswood Ltd (SME) Project

To evaluate the 0.2 kW PEM fuel cell and develop a compact fuel cell power unit with metal hydride store to power a small outboard motor, for about 1 working day.

Tested at Barnt Green sailing club Jan 2008

Hydrogen Fuel Cell Vehicle

- Weighs 500kg
- Maximum speed 40 mph
- Range, on a full hydrogen tank, of approximately 160km (100miles)
- Hydrogen stored at 350 bar in composite tanks

MICRO:CAB™

www.microcab.co.uk

Microcab is the product of entrepreneur John Jostins who visualised a small, urban vehicle with zero emissions suitable for use as a taxi or light freight carrier

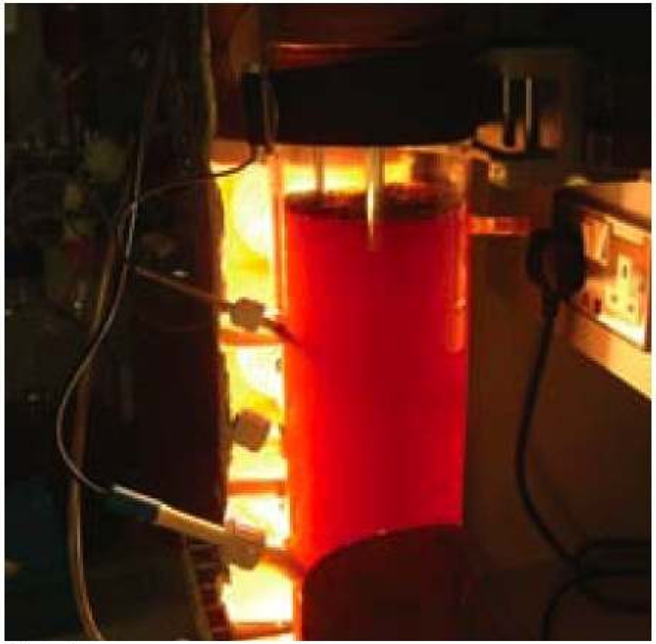
5 Integration

Hydrogen Fuelling Station - Univ. of Birmingham Campus

- Air Products Series 100 - fully commissioned April 08
- Compare 5 H2 FC vehicles with petrol fleet
- optimised to fuel up to 6 vehicles per day

Compressed to 450 bar in buffer tank

Production


Biohydrogen reactor

Storage


Metal hydride storage

Application

Hydrogen fuel cell vehicle

Economics

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Hydrogen and Fuel Cells: University of Birmingham

www.fuelcells.bham.ac.uk/

SCRATCH: Dr Waldemar Bujalski (W.Bujalski@bham.ac.uk)