

## Hydrogen and Fuel Cells: University of Birmingham



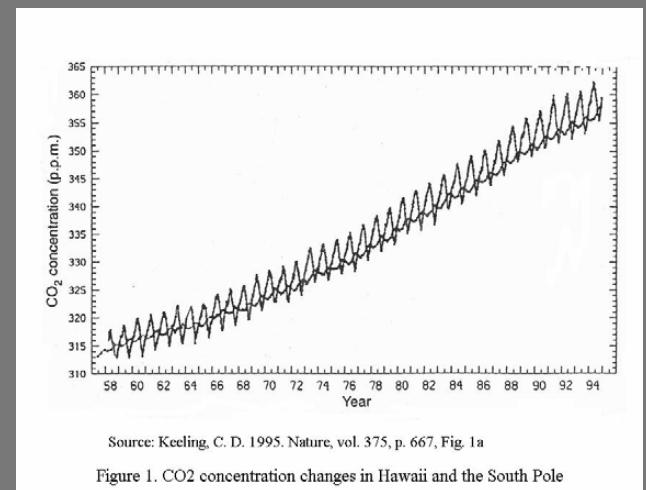
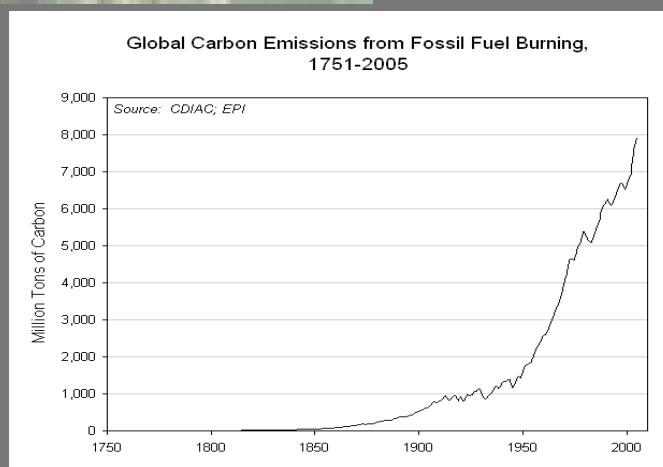
**Dr Bruno G. Pollet – [b.g.pollet@bham.ac.uk](mailto:b.g.pollet@bham.ac.uk)**  
Head of Proton Exchange Membrane Fuel Cell (PEMFC)  
Fuel Cell Group

[www.fuelcells.bham.ac.uk](http://www.fuelcells.bham.ac.uk)  
[www.hydrogen-wm-scratch.info](http://www.hydrogen-wm-scratch.info)

# *Tackling **GLOBAL WARMING** is urgent and **FOSSIL FUEL** prices are rising...*



Pictures courtesy of BBC website



- 7 Billion tons (min.) of CO<sub>2</sub> emitted to the atmosphere PA globally!!!!
- 30 Billion tons of coal & 13 Billion barrels of oil burned each year!

1 barrel: 0.317mt of CO<sub>2</sub> (min.)

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*‘Prime Minister Gordon Brown has committed the UK to reducing carbon dioxide (CO<sub>2</sub>) emissions by 60% before 2050 to help tackle global warming’*

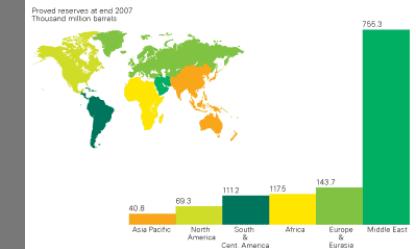
*The Climate Change Bill will make the UK the first country to put carbon emissions reduction targets into law...*

*while the bill will also enforce reductions of greenhouse gas emissions of between 26% and 32% by 2020*

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# GLOBAL ISSUES

- CO<sub>2</sub> & Global Warming
  - Improved fuel efficiency and non carbon fuels favoured
- Oil production to peak in 2010-2020 (?)
  - Most oil produced from a few giant fields - production from these fields will peak around 2015
  - 2007 Oil Reserves stand at 1237.9 billion barrels (BP estimate)
  - This will encourage alternative fuels
- Population growth ....
  - Longer life expectancy → rise in world population from 6.3 Billion to 9 Billion over next 45 years is inevitable!
  - Improved pollution standards required just to keep up!



# Hydrogen and Fuel Cell Technologies: for a low carbon future...

*....one possible solution!*

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*‘It is predicted by 2050, Hydrogen and Fuel Cells technologies will have an important impact in the UK... a multi-million pound market!’*

*UK government, 2005*

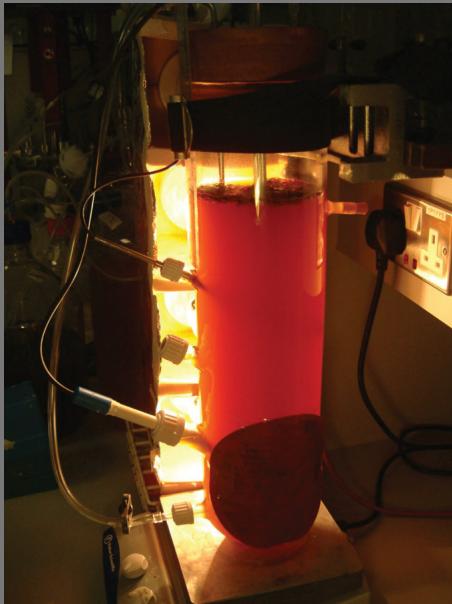
***TOMORROW’S ENERGY will be from FUEL CELLS using HYDROGEN to generate ELECTRICITY!***

*NewScientist, 2007*

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# Hydrogen Cycle

Production



Storage



Applications



Economics

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## 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

## 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

## 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

# Energy Technologies Institute

### 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 13 Sept 08  
Outcomes followed up to 5 yrs

### Manpower:

• 5 Scientists and 1 Technical to carry out delivery on ECTI

### Tasks:

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

### Deliverables:

- Strategy paper for hydrogen
- Hydrogen demonstration
- Final report

### Outputs:

• Increase profile of region and universities in H<sub>2</sub> 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  
• 1st Oct 2007 – 30 Sept 2011

# Joint Technology Initiative

**€1 billion over 10 years**

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

Started April 2008

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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 →  $H_2$
- Electrolysis: Water →  $H_2 + O_2$
- Hydrocarbon (Reforming)
- Photoelectrochemical Water Splitting
- Other possible methods BUT not cost effective!

- Hydrogen Production
- Hydrogen Storage
- Hydrogen Applications

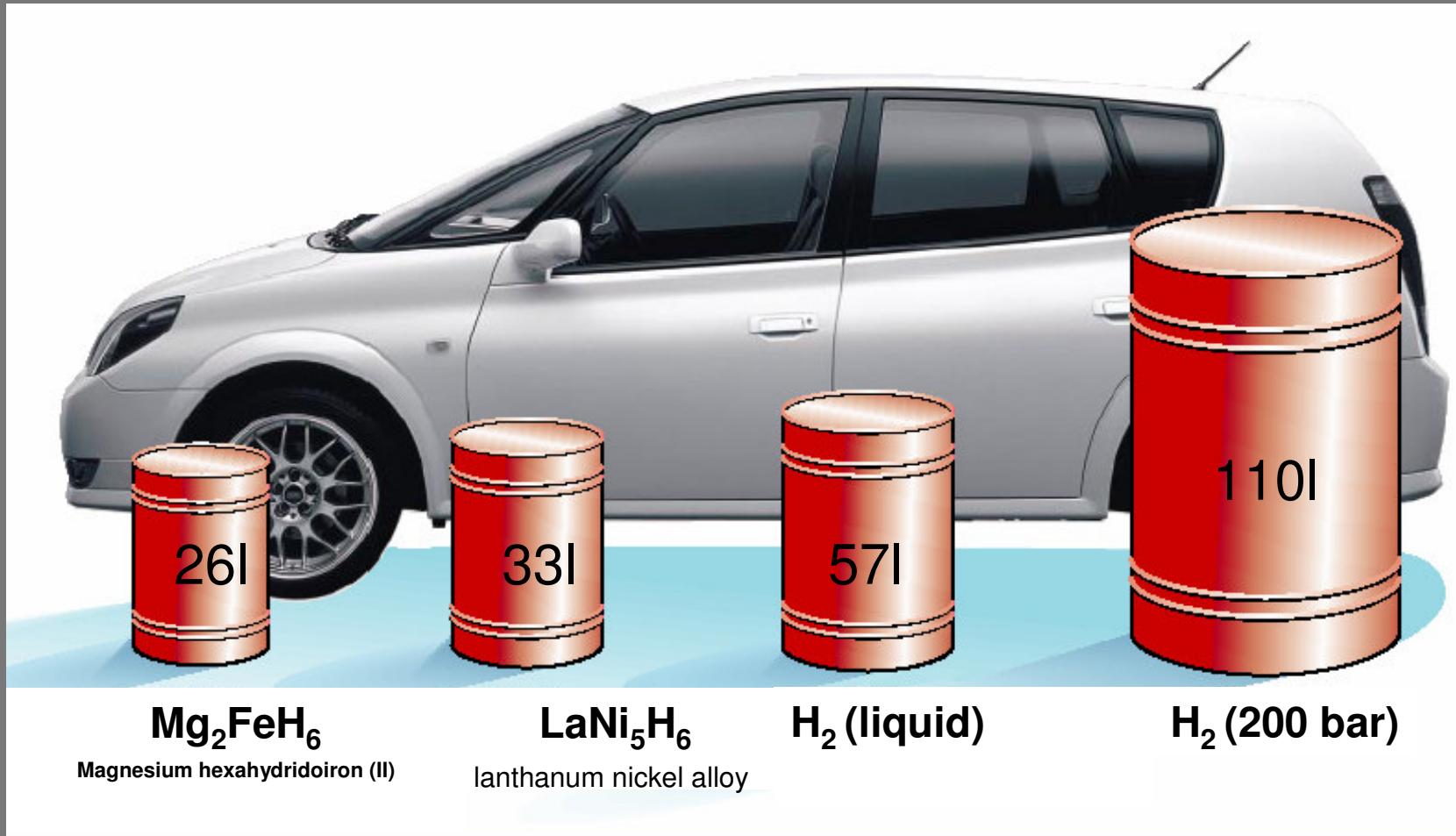
# Solid-state Hydrogen Storage Materials & Synthesis

- New potential hydrogen storage material:
  - $\text{Li}_4\text{BH}_4(\text{NH}_2)_3$
  - Combination of Amine Boranes with  $\text{MgH}_2$  and  $\text{LiNH}_2$  for High Capacity Reversible Hydrogen Storage
- Synthesis and Characterisation: casting (conventional and rapid quenching), ball-milling, thin-film preparation (PLD and Magnetron sputtering)

# VOLUME OF HYDROGEN STORAGE

4 kg hydrogen

3 l gasoline / 100 km = 0.3 kWh / km



Louis Schlapbach & Andreas Züttel, NATURE |  
VOL 414 | 15 NOVEMBER 2001 | pp. 353-358

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# Requirements for Hydrogen Stores

- High H atoms content per unit mass of metal
- Low cost
- Absorb & Desorb Hydrogen around 1 atm @ RT
- Low heat of formation of hydride ~ 9kcal/mol H<sub>2</sub>
- Reproducible & favourable reaction kinetics
- Not readily poisoned by gaseous impurities
- Safe on exposure to air

- Hydrogen Production
- Hydrogen Storage
- Hydrogen Applications

## FUEL CELLS LABS

*Head: Prof. Kevin Kendall, FRS*



Dr Waldemar Bujalski



Dr Bruno G. Pollet

### SOFC R&D

- SO Fabrication Facilities
- SOFC Test Stands
- System Integration



### PEMFC R&D

- MEA Fabrication Facilities
  - PEMFC Test Stands
  - System Integration

## Application & Demonstration

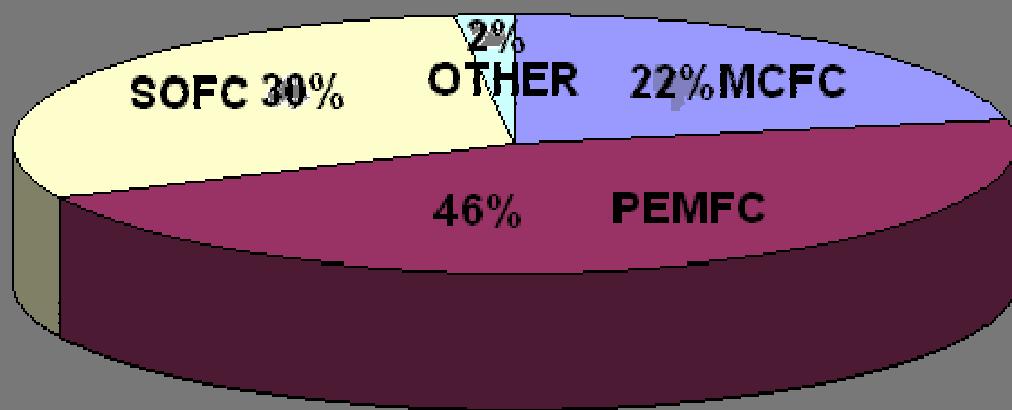
*Stationary & Transportation*

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# Fuel Cells Technologies

<u>Fuel Cell Type</u>	<u>Electrolyte</u>	<u>Anode Gas</u>	<u>Cathode Gas</u>	<u>Temp.</u>	<u>Eff.</u>
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%

# 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

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# PEMFC Commercialisation Roadmap

## *Potential Penetrable Markets*

Portable, Residential (CHP) Stationary, Fleet Transportation and Automotive



Courtesy: JMFC Ltd

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## Hydrogen and Fuel Cell Supply Chain

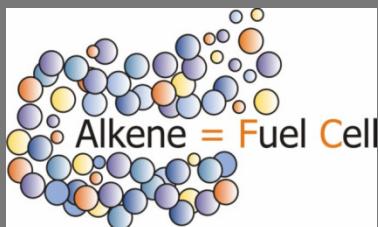
- Outline possible supply Chains leading to the hydrogen & fuel cell economy
- Focus on biomass, hydrogen storage, fuel cell CHP & vehicle, and economic barriers
- Bring min. 30 companies together in supply chain
- Zero Emission campus → ZE country

# Our Objectives

- (i) Develop the Science, Technology and **Supply Chain** for Hydrogen and Fuel Cells
- (ii) Generate new technologies, employment, growth, a wealthy Hydrogen and Fuel Cells economy as well as international reputation
- (iii) Involve local SMEs to take part in the Supply Chain for Hydrogen and Fuel Cells

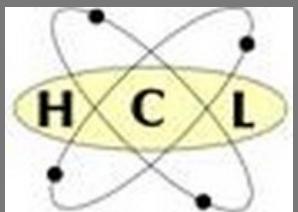
# UK West Midlands H2&FC Suppliers

Adelan Ltd



Bailey & Mackey Ltd

KATRONIC



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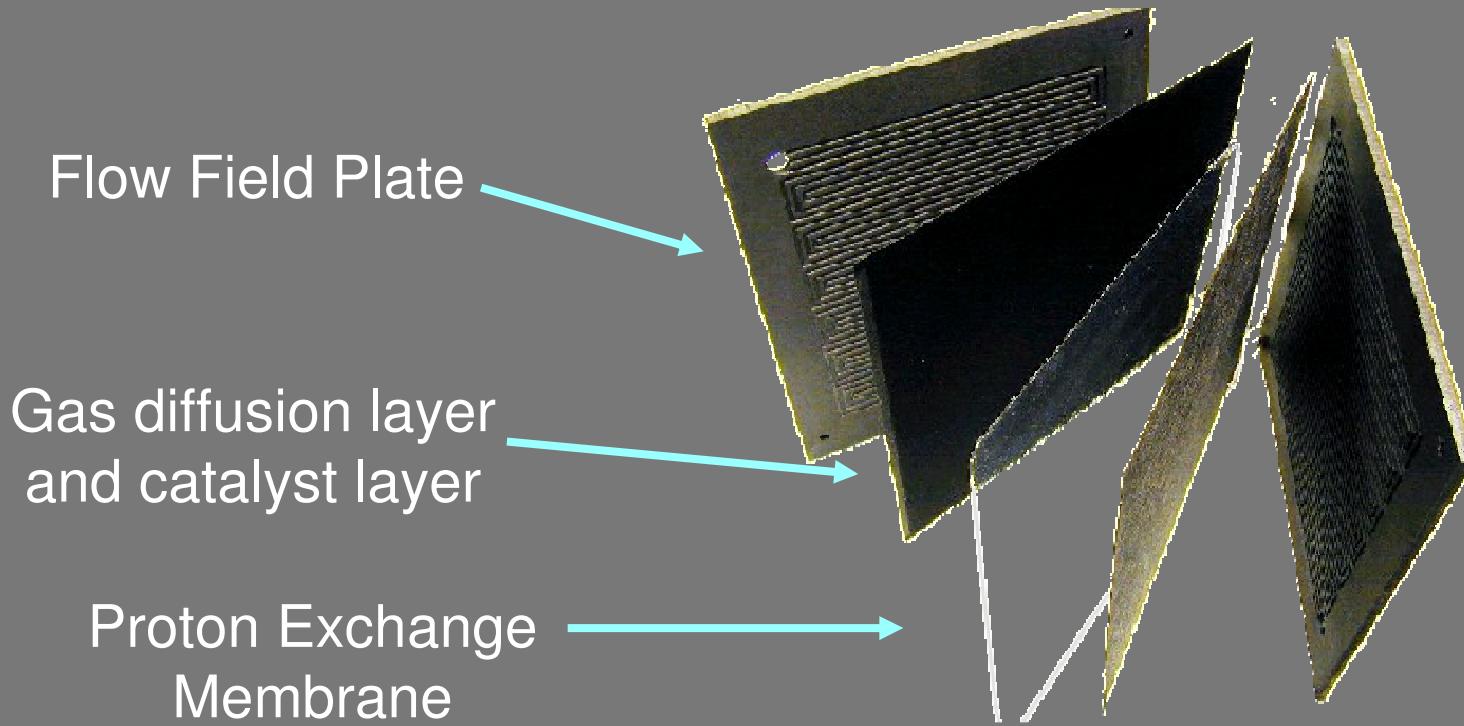
# Problems to be solved!

- Source of Green Hydrogen
- Distribution & Infrastructure
- Utilisation by fuel cells
- Economic drivers

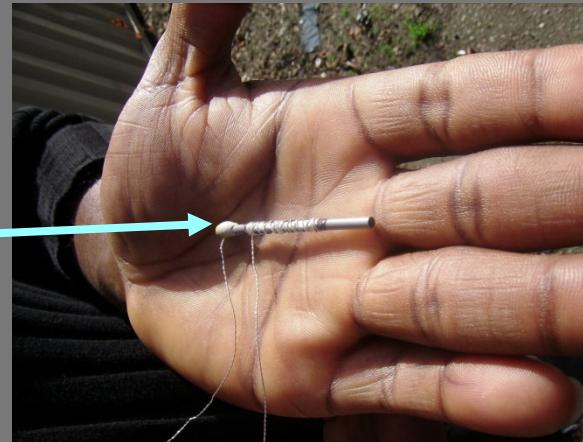
# Economic Drivers

- Collaboration with Professor Richard Green
- Main objective is to understand costs
- Explicit costs: e.g. hydrogen & fuel cell cost
- Hidden costs: e.g. barriers to grid connection

# Our Key Research Areas



Microtubular SOFC



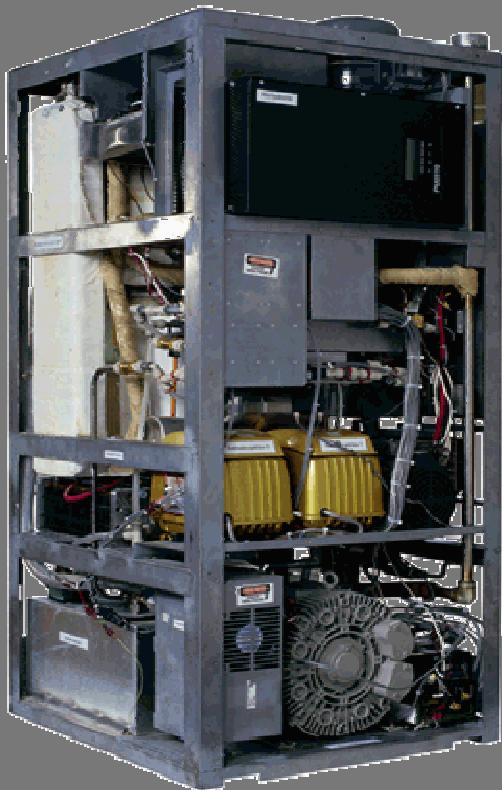
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# Our Key Research Areas

- Low cost, high performance & durable 'engineered' fuel cell electrodes
- 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 novel type of electrocatalysts and noble base metal alloys as Nanoparticles
- Developing & testing non-noble metal electrocatalysts in views of reducing cost while improving on performance and durability

# Successful Projects

Combined Heat and Power  
System for domestic applications



*Example of successful project  
using Hydrogen Fuel Cell for  
household applications*

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# House in the West Midlands heated by a Hydrogen Fuel Cell

PEMFC

Fuel:  
Natural Gas & Air

The fuel cell has  
a dual purpose:

- (i) Supply of electricity
- (ii) Heating



# **MicroCab** Hydrogen Fuel Cell Vehicle

*Example of successful project using Hydrogen Fuel Cell for the automotive industry*



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# Successful Projects

## Hydrogen Fuel Cell Narrow Boat



The Protium Project

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# The Midland Hydrogen Ring

- The British Midlands Hydrogen Forum is to establish the 'Midlands Hydrogen Ring' – a series of fuelling stations across the region for hydrogen vehicle development and testing activity, which will link up with similar facilities in neighboring areas
- The Hydrogen Ring will raise the Midlands' profile as a region seriously engaged in the development of low-carbon transport technologies, and will draw additional activity into the region
- The second hydrogen fuelling station is already under construction at Loughborough and the BMHF as recently secured funding from both *emda* and AWM for a scoping study, which will see the rollout of this exciting project



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# Hydrogen Fuelling Station at the University of Birmingham

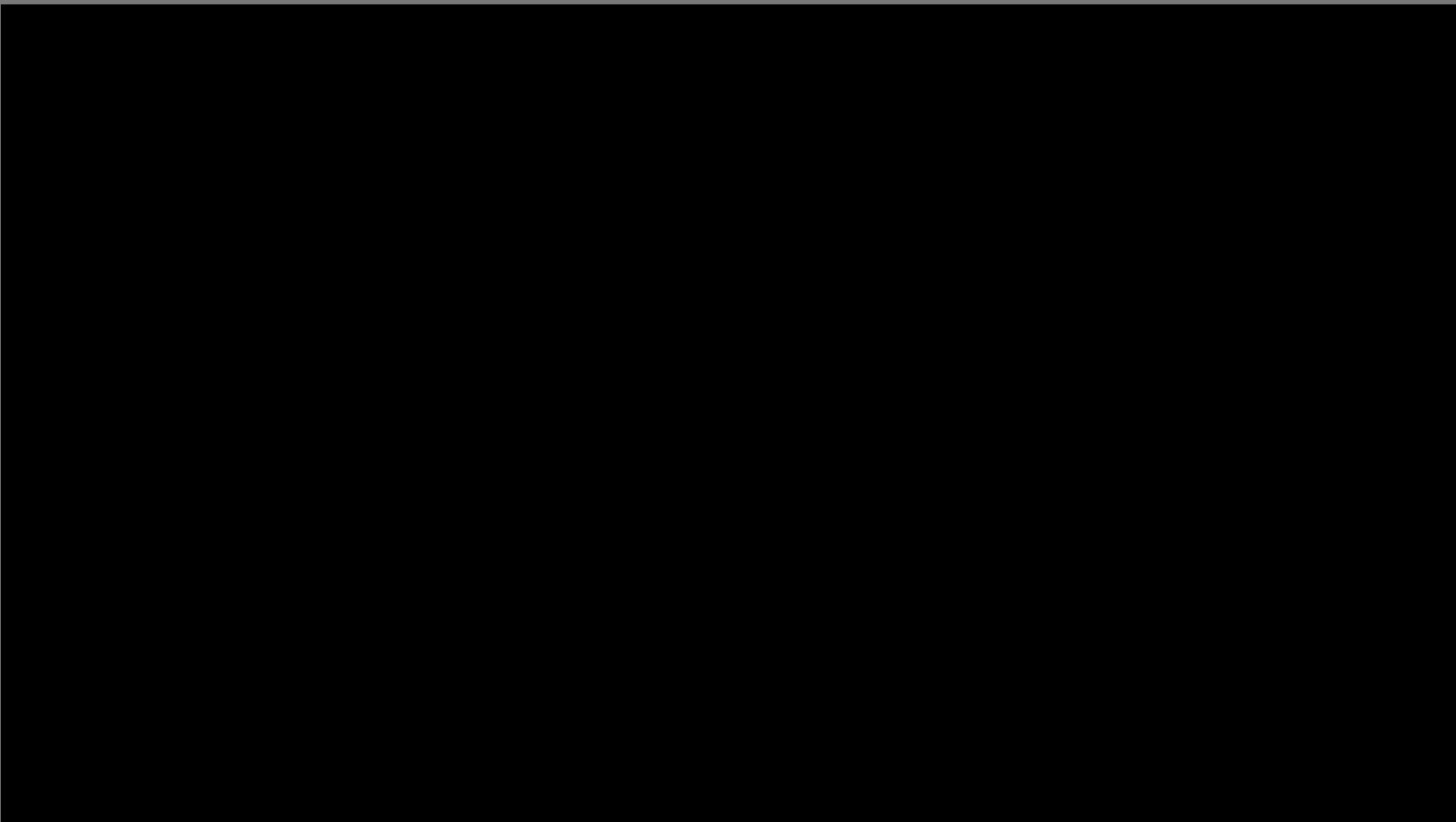
Air Products, fully commissioned

April 08



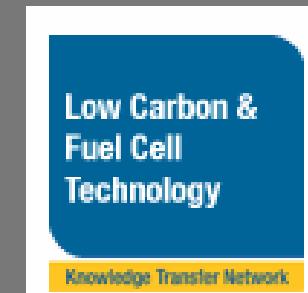
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# BBC NEWS LIVE - 17<sup>th</sup> April 2008



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# Acknowledgement



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# U

Fuel cell technology will have an enormous impact across all energy markets...  
Birmingham will be the catalyst for this revolution in sustainable technology.



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