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Hydrogen and Fuel Cells:
University of Birmingham



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Head of Proton Exchange Membrane Fuel Cell (PEMFC)

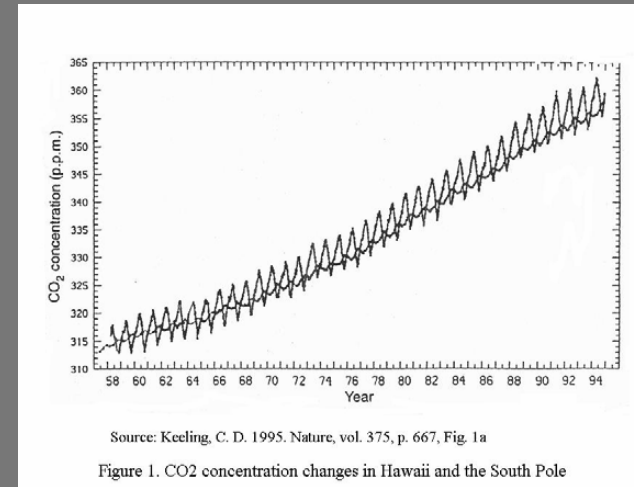
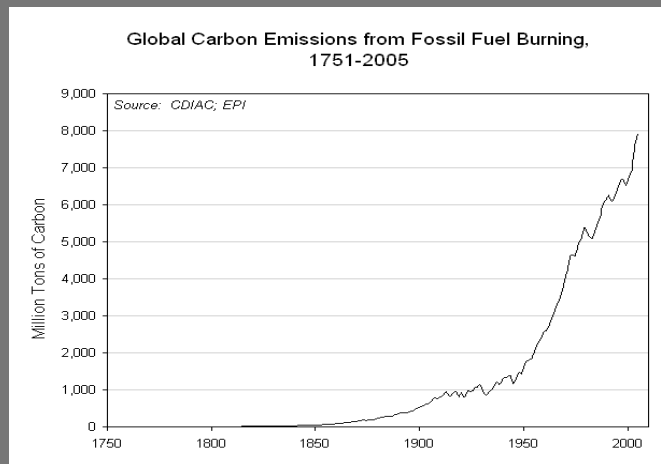
www.fuelcells.bham.ac.uk
www.hydrogen-wm-scratch.info

Exploratory Energy Workshop, Bucharest – 17th – 19th September 2008

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



Pictures courtesy of BBC website



- ❑ 7 Billion tons (min.) of CO₂ emitted to the atmosphere PA globally!!!!
- ❑ 30 Billion tons of coal & 13 Billion barrels of oil burned each year!

1 barrel: 0.317mt of CO₂ (min.)

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'Prime Minister Gordon Brown has committed the UK to reducing carbon dioxide (CO₂) 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...

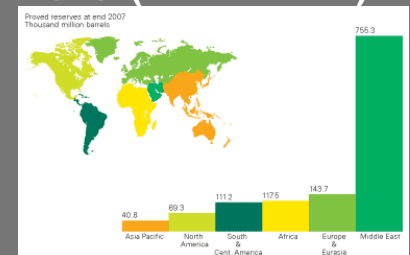
while the bill will also enforce reductions of greenhouse gas emissions of between 26% and 32% by 2020

GLOBAL ISSUES

- CO₂ & Global Warming
 - Improved fuel efficiency and non carbon fuels favoured
- Oil production to peak in 2010-2020 (?)
 - Most oil produced from a fewer 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!

'It is predicted by 2050, Hydrogen and Fuel Cells technologies will have an important impact in the UK... a multi-billion pound (ca. £10B in 2013 globally) market!'

UK government, 2005

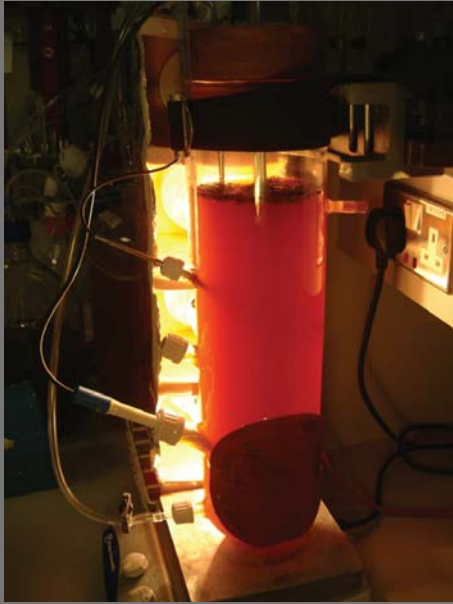
TOMORROW'S ENERGY will be from FUEL CELLS using HYDROGEN to generate ELECTRICITY!

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 - **£1.5M**
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" **£6.4M**
Started December 2006

Energy Technologies Institute

Universities of Birmingham, Nottingham & Loughborough

> £600M (possibly up to £1B) over 10 years

Joint Technology Initiative

€1 billion over 10 years

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

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Outputs:

- 30 business assistance
- 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 2011
Outcomes followed up to 5 yrs

Mannpower:

5 Scientists and 11 technician to carry out deliverables

Tasks:

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

Deliverables:

- Significant progress in hydrogen supply chain
- Final report

Outputs:

- Increase profile of region and universities in H₂ 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
to the December 2011

How we produce Hydrogen

- Biohydrogen: Food wastes + bacteria → H₂
(bioreactors)

[AVIs\PR Hydrogen Video.avi](#)

- Supercritical Water Gasification (SWG): Dissolution of Organic compounds & lignocellulosic materials, as solid biomass in SC water at elevated temperature → H₂
- Electrolysis: Water → H₂ + O₂
- Hydrocarbon (Reforming)
- Photoelectrochemical Water Splitting
- Other possible methods BUT not cost effective!

- Hydrogen Production
- Hydrogen Storage
- Hydrogen Applications

Solid-state Hydrogen Storage Materials & Synthesis

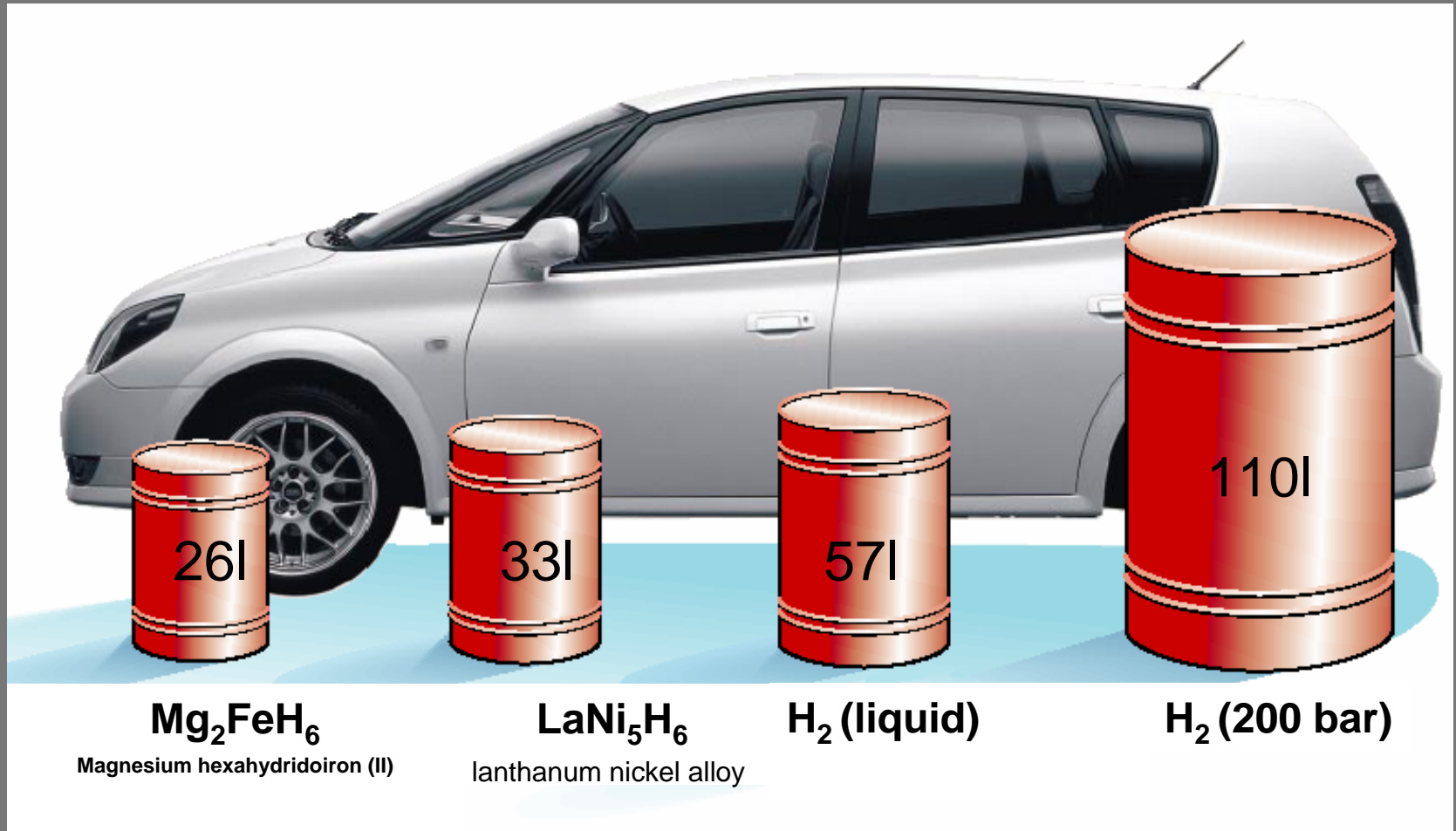
- New potential hydrogen storage material:
 - $\text{Li}_4\text{BH}_4(\text{NH}_2)_3$
 - Combination of Amine Boranes with MgH_2 and LiNH_2 for High Capacity Reversible Hydrogen Storage

- 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



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 H₂
- 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

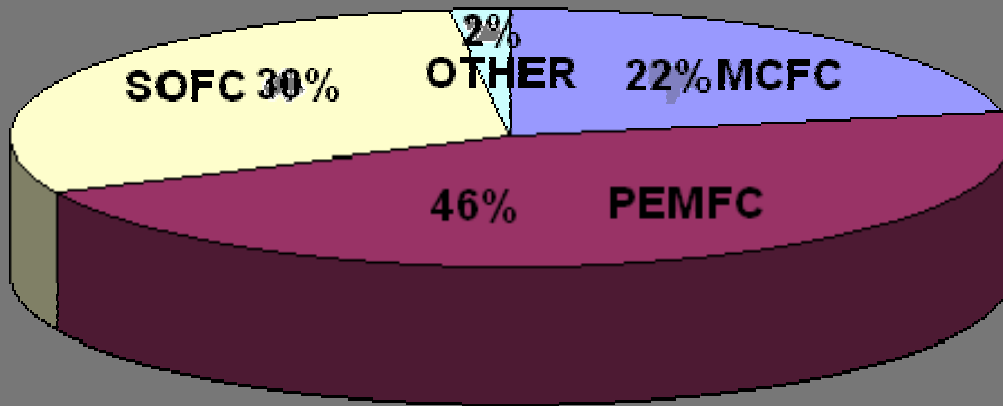
- MEA Fabrication Facilities
- PEMFC Test Stands
- System Integration

Application & Demonstration
Stationary & Transportation

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

PEMFC Commercialisation Roadmap

Potential Penetrable Markets

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

Predicted Number of FCs



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

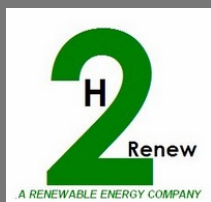
(i) Develop the Science, Technology and **Supply Chain** for Hydrogen and Fuel Cells

(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



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Problems to be solved!

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

Economic Drivers

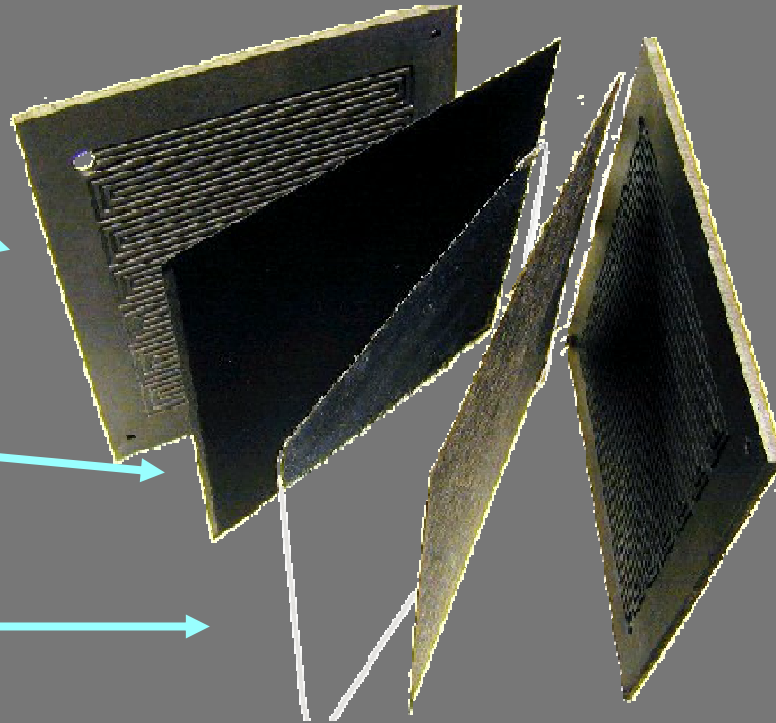
- Collaboration with Professor Richard Green
- Main objective is to understand costs
- Explicit costs: e.g. hydrogen & fuel cell cost
- Hidden costs: e.g. barriers to grid connection

Our Key Research Areas

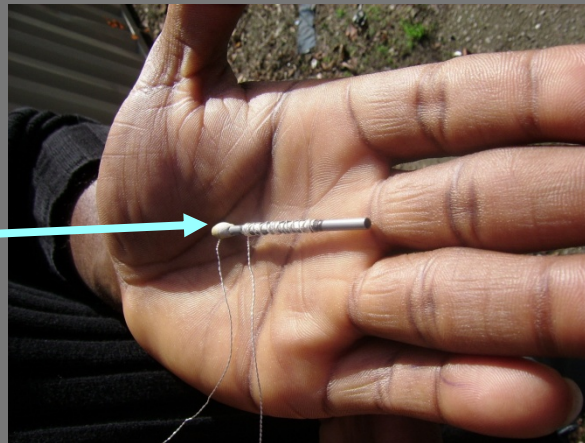
Flow Field Plate

Gas diffusion layer
and catalyst layer

Proton Exchange
Membrane



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

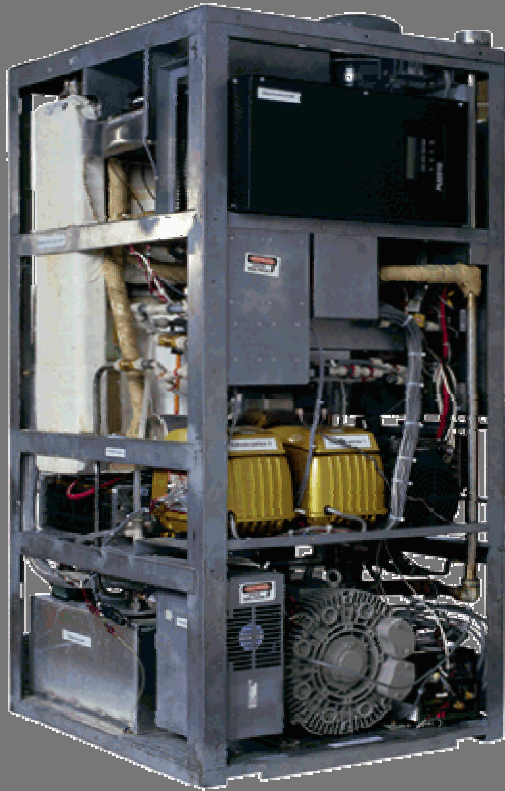
Successful Projects

Micro-tubular SOFC Demonstrator

[AVIs\SOFC-demonstrator-watermarked.avi](#)

Successful Projects

Combined Heat and Power
System for domestic applications



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

House in the West Midlands heated by a Hydrogen Fuel Cell

PEMFC

Fuel:
Natural Gas & Air

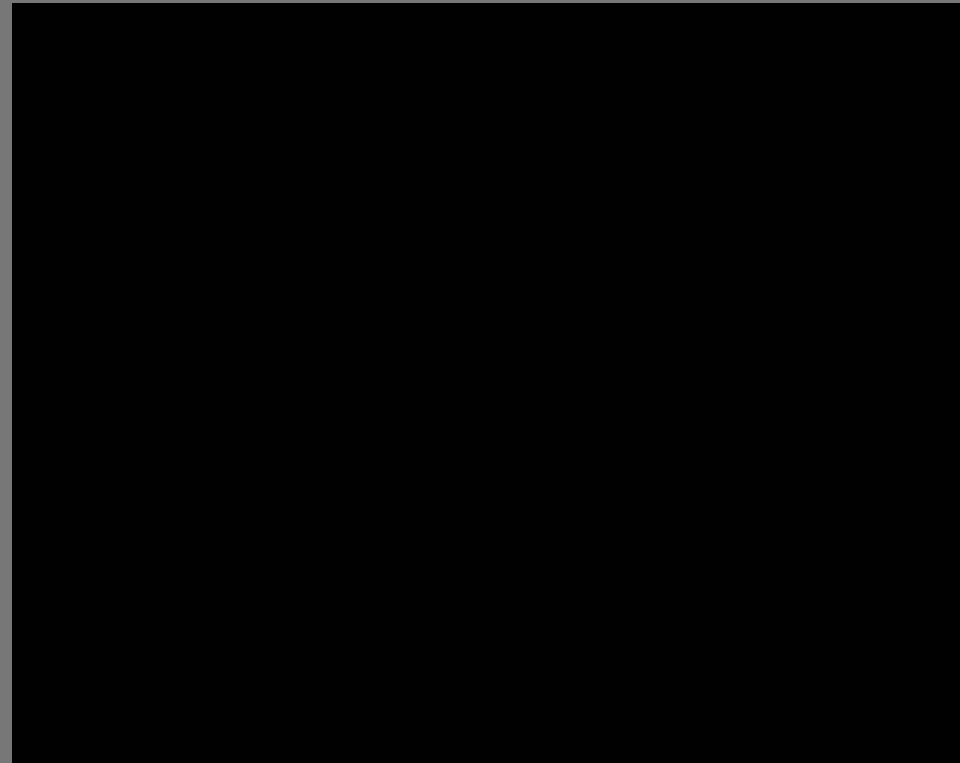
The fuel cell has a dual purpose:

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



Microcab Hydrogen Fuel Cell Vehicles

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



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Successful Projects

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

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 has 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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Hydrogen Fuel Cell Conference: Building the Hydrogen and Fuel Cells Future

25th March 2009, NEC
Birmingham, England, U.K.

www.climate-change-solutions.co.uk

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Vacancies & Collaborations

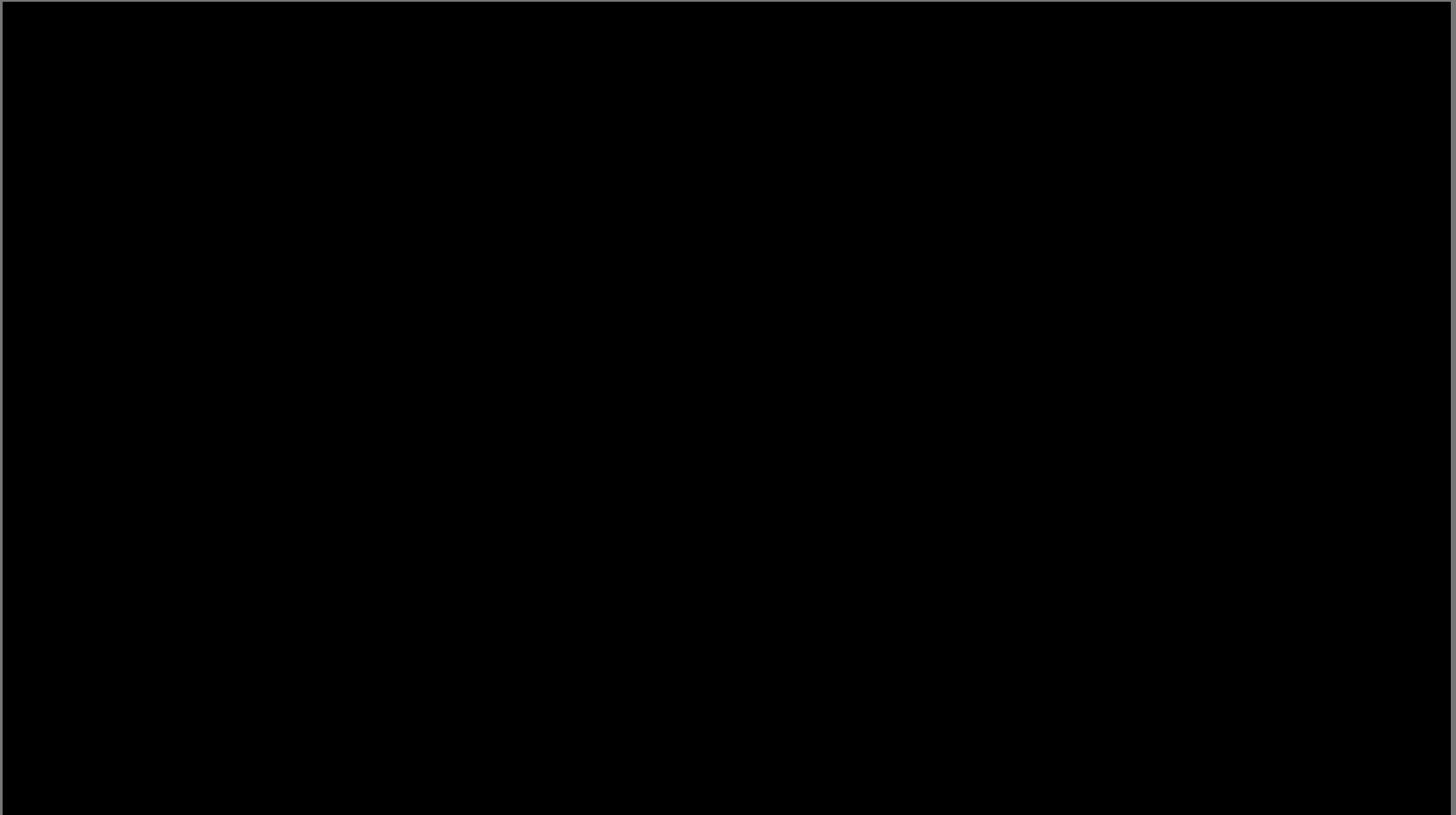
PEMFC & SOFC

- Work placement Industry & FC/SE Research Labs
 - PhD Studentships
 - PDRFs

FP7 & JTIs

Seeking partnership in FP7 projects

BBC NEWS LIVE - 17th April 2008



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Acknowledgement

Industry & Research Funding Bodies

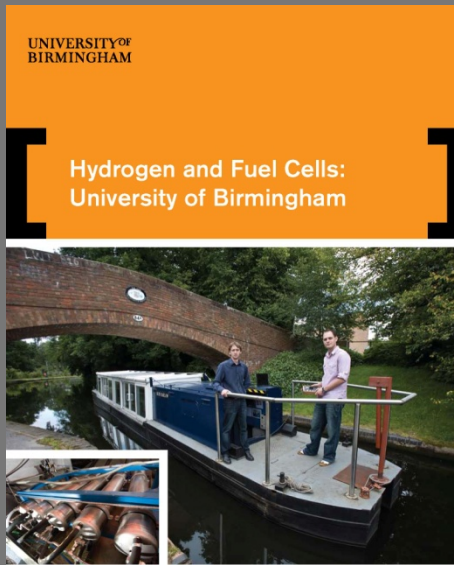


Johnson Matthey Fuel Cells
— the power within



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Thank you!

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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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**For further info, please
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