



Imperial College London

The case for UK investment in fuel cell technology

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Introduction

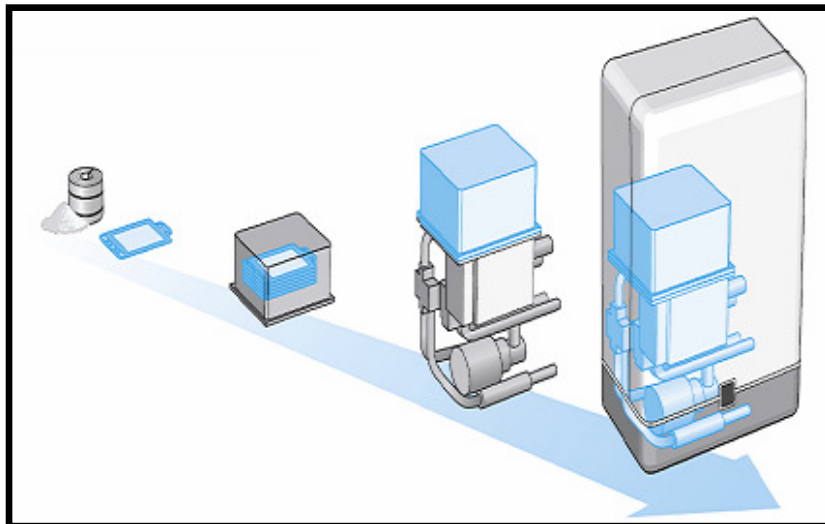
- Why Fuel cells?
- Why should the UK invest in fuel cells?
- Opportunities and challenges in Solid Oxide Fuel Cells.
- Opportunities and challenges in Polymer fuel cells.
- Conclusions.

So why are fuel cells of interest?

- A fuel cell is an electrochemical engine – it converts fuel and air electrochemically into electricity and heat.
- Fuel cells have the highest known efficiency of any energy conversion device – an efficiency which further increases at part load.
- By avoiding combustion fuel cells produce extremely low levels of NO_x and particulates.
- Fuel cells are quiet, modular and can be used in a wide range of global mass market applications.

Applications by fuel cell type

Solid Oxide Fuel Cell



Polymer Fuel Cell

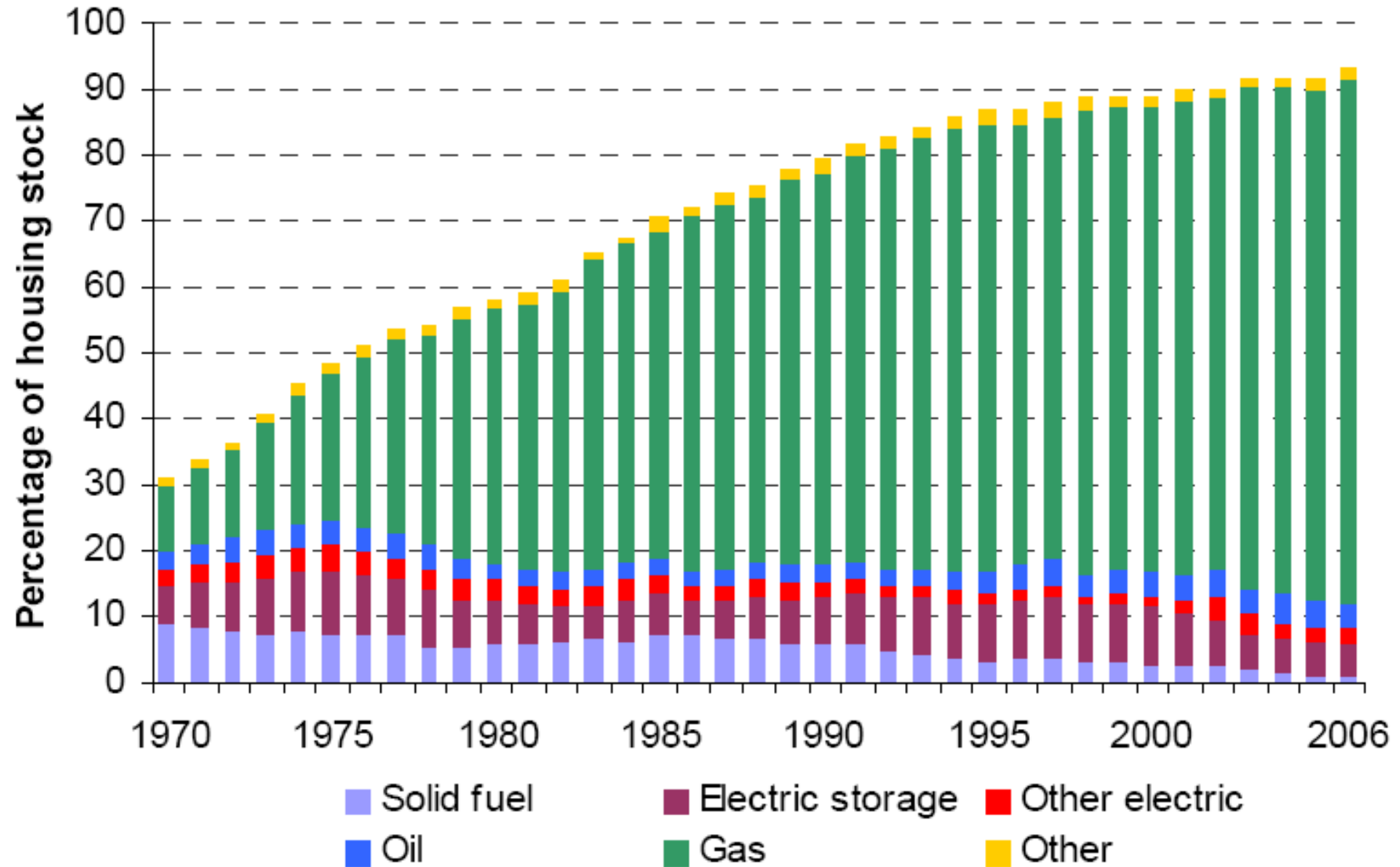


Solid Oxide Fuel Cells in the UK

- Focus is on natural gas for stationary systems, with the potential to operate on renewable fuel e.g. biogas and/or hydrogen.
- Elevated temperature (500-1000C) means SOFCs are fuel flexible and produce high grade waste heat.
- Efficiency is high; ~40% for 'small' (kW_e) stand alone systems to 70% for 'large' (MW_e) gas turbine hybrids.
- SOFCs contribute to UK targets for CO₂ reduction and energy security.
- Globally leading UK product development companies; e.g. Rolls-Royce FCS and Ceres Power.

UK: Ownership of central heating

40% of UK CO₂ emissions are due to heating, 33% to electricity



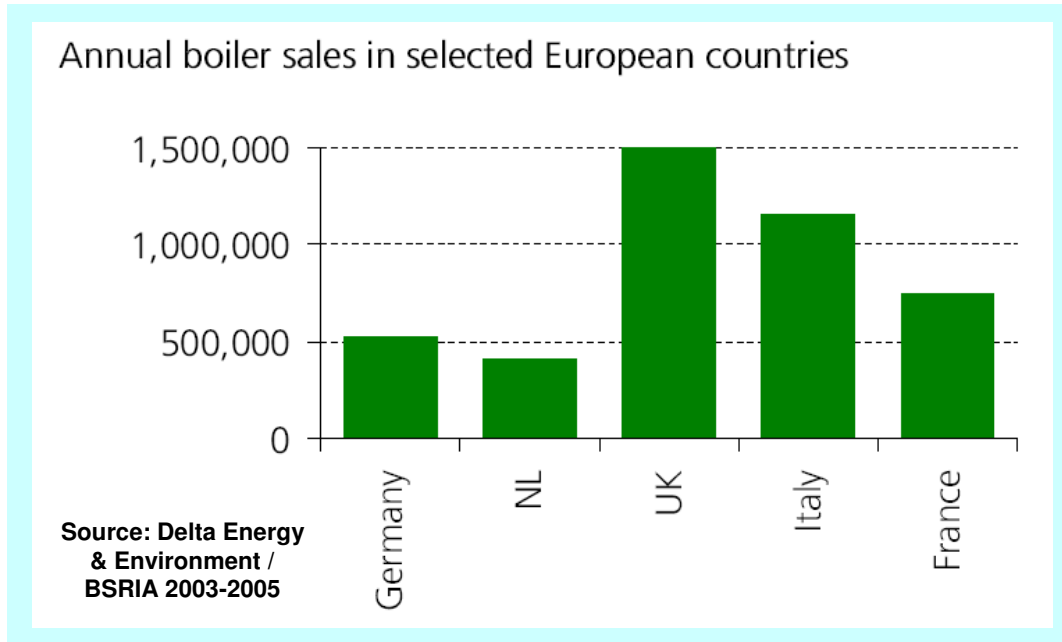
Source: GfK Home Audit from the Domestic Energy Fact File. Building Research Establishment.

Ceres Power SOFC micro-CHP unit

- Developed in collaboration with British Gas (with natural gas fuel) and Calor Gas (with LPG fuel).
- Prototype unit demonstrated.
- Reduces the energy bill of a customer by around 25% and saves up to 1.5 tonnes CO₂ per annum per household – use on biogas would deliver high efficiency and renewable heat and power.



The boiler market is an International Opportunity



- Boiler sales across the top 5 European markets alone, are over 4.5 million per annum

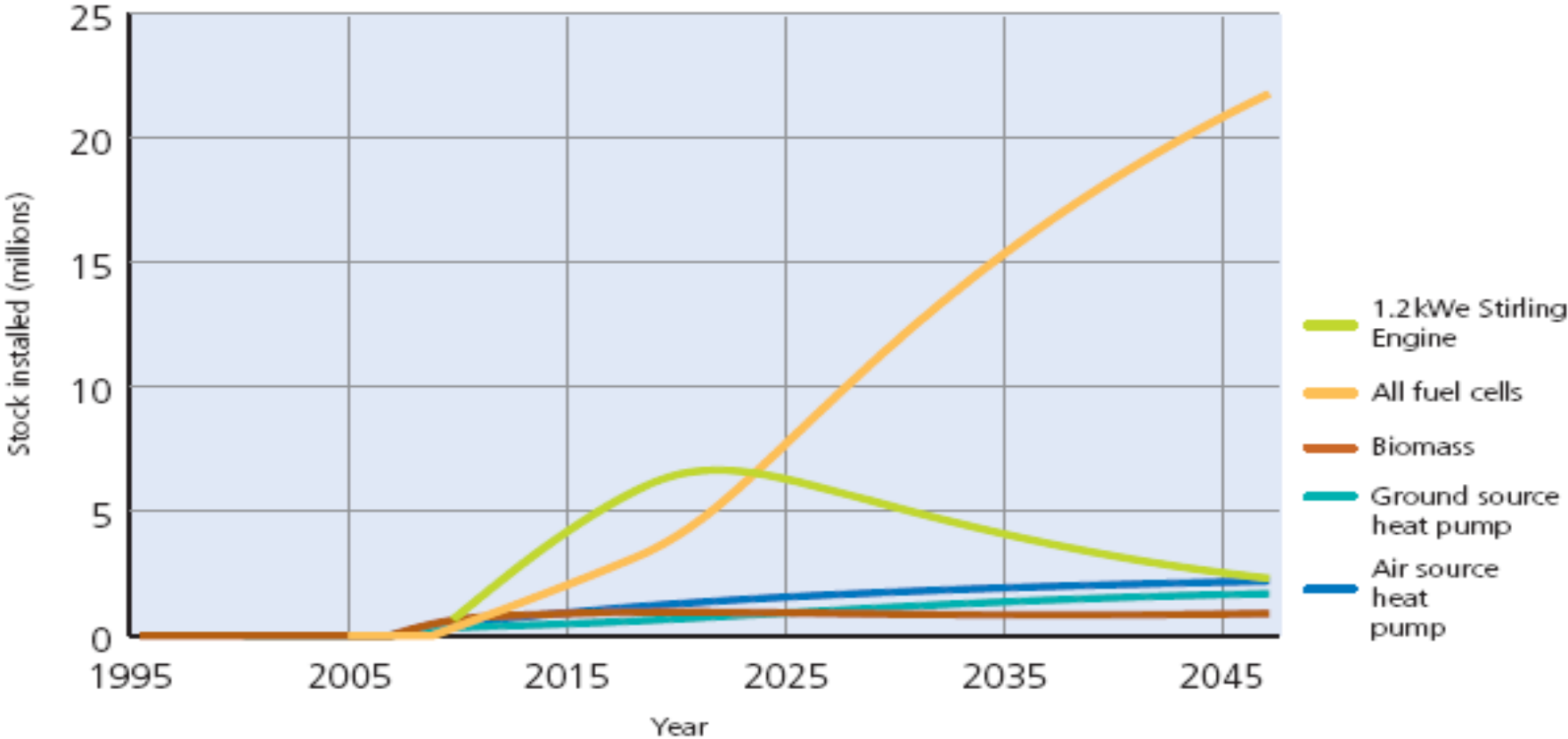
Source: Frost & Sullivan, 2003

- An integrated wall mountable product is a pre-requisite for mass market adoption across European markets

Country	Wall Hung as % of Boiler Sales
UK	85%
Netherlands	96%
Germany	58%
France	75%
Italy	84%

Source: Energy Saving Trust 2007

Fuel cell mCHP is a Mass Market Technology



Fuel cell mCHP highlighted by recent independent studies as the leading mass market microgeneration technology for UK

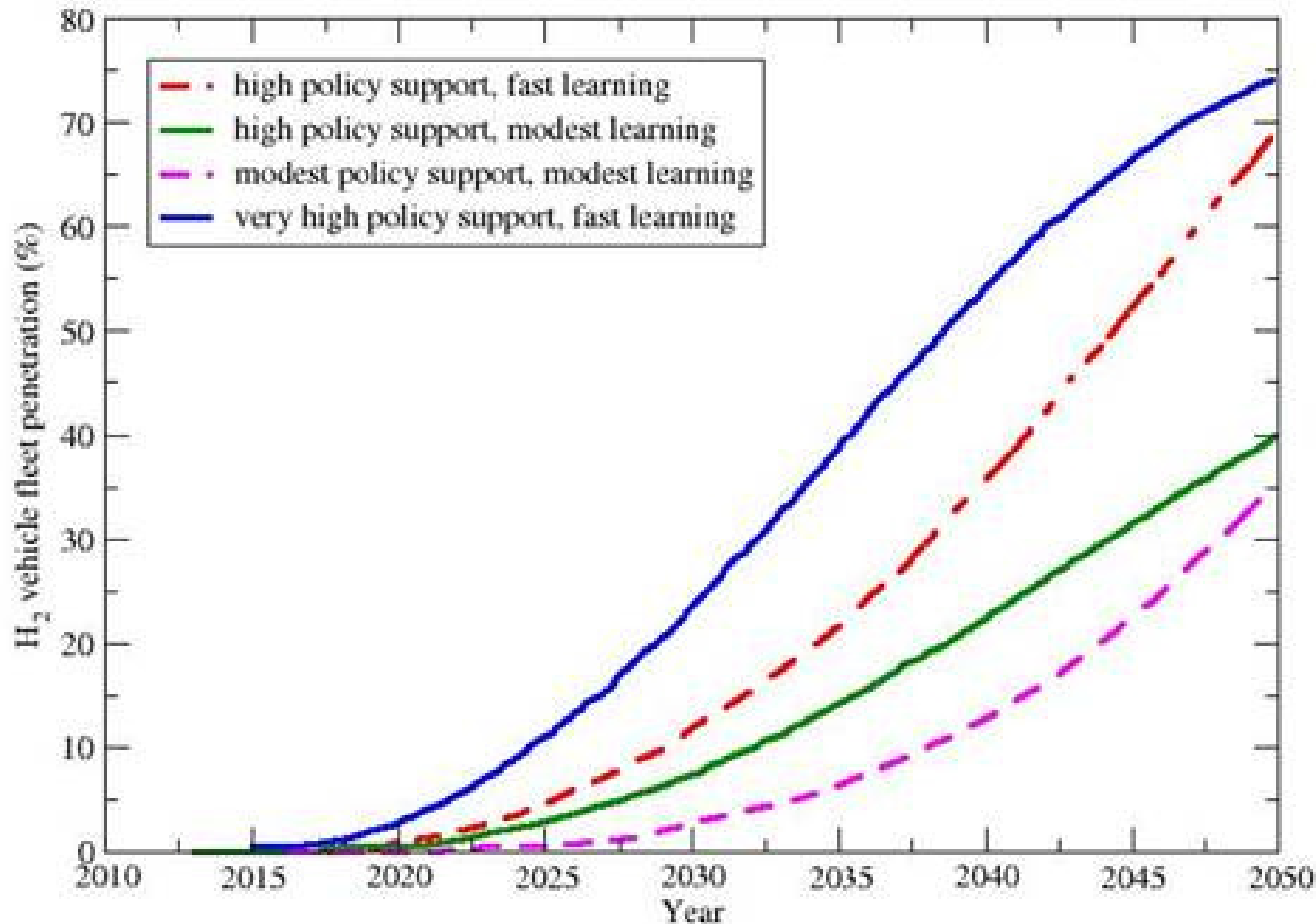
What are the SOFC materials challenges?

- Commercial cost targets can be met, and industry has the materials set needed for product entry.
- Research challenges therefore lie in developing the materials engineering knowledge and tools needed to support product launch and future product development.
- In particular understanding and mitigating failure modes in real world operation is critical, as is the development of accelerated testing methods and materials lifeing tools.
- A future biogas variant would need improved anode materials.

Polymer Fuel Cells in the UK

- Focus on hydrogen for transport applications.
- Potential to contribute to a 'public good' agenda through zero emission (at point of use) vehicles.
- Potential to de-carbonise the transport sector if hydrogen is produced from nuclear, renewables, or with CCS.
- Contributes to UK targets for CO₂ reduction and energy security.
- Globally leading commercial supply chain and product development companies; e.g. Johnson Matthey, Intelligent Energy, ACAL energy.

Hydrogen fuel cell vehicle penetration in EU



Scenarios on the rate of penetration of hydrogen-fuelled road vehicles in the EU (adapted from the HyWays Roadmap). Note: the fast learning scenarios assume that mass manufacturing of vehicles starts in 2013, while slow learning scenarios delay this until 2016.

What are the PEMFC materials challenges?

- Fuel cell products have demonstrated functionality and lifetime in real world conditions.
- But commercial cost targets for mass market applications cannot be met with current materials – fuel cell costs need to be reduced by a factor of ten.
- Materials sit at the heart of this challenge, with innovation in all aspects of the materials supply chain, with the need for low cost catalysts, electrolyte membranes, and interconnect plates, but without loss in performance.
- Supporting progress in hydrogen storage, and in low cost routes to ‘low carbon’ hydrogen, is also essential.

Summary

- Fuel cells can play a critical role for the UK in reducing carbon emissions from heat and power by 2020 and beyond, and in low carbon vehicles beyond 2020 when coupled with low carbon routes to hydrogen.
- The UK has world-class fuel cell supply chain and product development companies supported by an excellent science base, and is therefore well placed to develop jobs and value for UK plc in this sector.
- Fuel cell mCHP products based on SOFCs are close to commercial launch. They will reduce CO₂ emissions from natural gas in the near term, with the option to run on biogas in the longer term. Support for materials engineering is needed to improve product lifetime, and future product development. New anode materials will be needed for biogas.
- Hydrogen PEMFC engines for bikes, cars and buses are the subject of world wide demonstration programmes. These have demonstrated functionality and lifetime, but the costs of the core fuel cell stacks need to be reduced by a factor of ten or more for mass market uptake. This can only be achieved by materials innovation in all aspects of the fuel cell.
- All fuel cell products require cost intensive product engineering - at present funding schemes in the UK do not adequately support this phase of product development.