H2FC SUPERGEN

THE HYDROGEN AND FUEL CELL RESEARCH HUB

The H2FC Hub: Identifying the opportunities for Hydrogen and Fuel Cells in the UK

Zeynep Kurban, PhD

FCH2 Technical Conference 14th March

Research Councils UK Energy For a Low Carbon Future

www.h2fcsupergen.com

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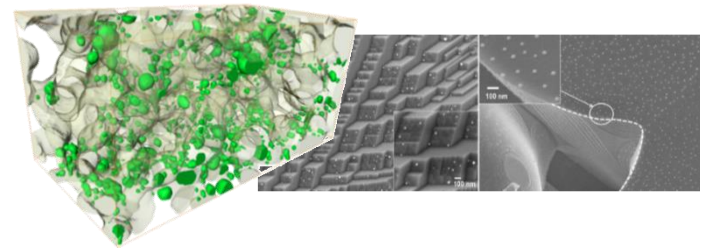
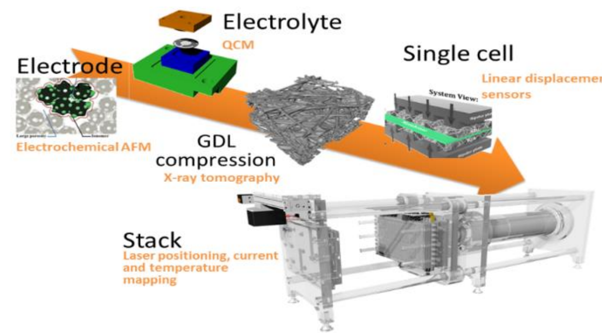
Aims and Objectives

The Hydrogen and Fuel Cells **(H2FC) SUPERGEN** hub**,** funded by the *Research Council's UK Energy Programme* (May 2012-April 2019).



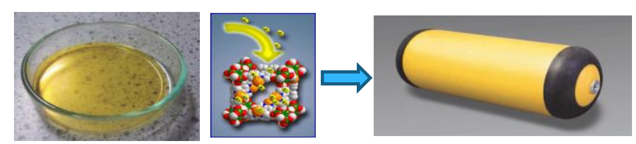
Three primary functions:

Transformational Research that enables the application of hydrogen and fuel cells in the energy landscape



Informing Stakeholders of the roles and benefits of hydrogen and fuel cell technologies

Building Networks between the academic research base and industry, builds partnerships across the sector



SUPERGEN is part of the UK Energy Programme's ***Su****stainable* ***P****ow****er*** ***Gen****eration and Supply initiative (****SUPERGEN****).*

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Hub Research

21 UK + 8 International Universities, £20m over 7 years

Core Hub Research Universities

Imperial College London
University of Bath
UCL
Ulster University
University of Birmingham
University of St Andrews
Newcastle University

Other UK Universities with Hub Projects

University of Liverpool
University of Surrey
University of Oxford
Lancaster University
University of Exeter
The University of Nottingham, United Kingdom · China · Malaysia
University of Strathclyde Glasgow
University of South Wales
Queen Mary University of London
Loughborough University
University of Reading
The University of Warwick
University of Southampton
The University of Edinburgh

International Partner Universities

University of Cape Town, Iyunivesithi Yasekapa • Universiteit van Kaapstad
浙江大學 Zhejiang University
DTU
MIT
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Hanbat National University, since 1927
Soongsil University 1897
Kyushu University

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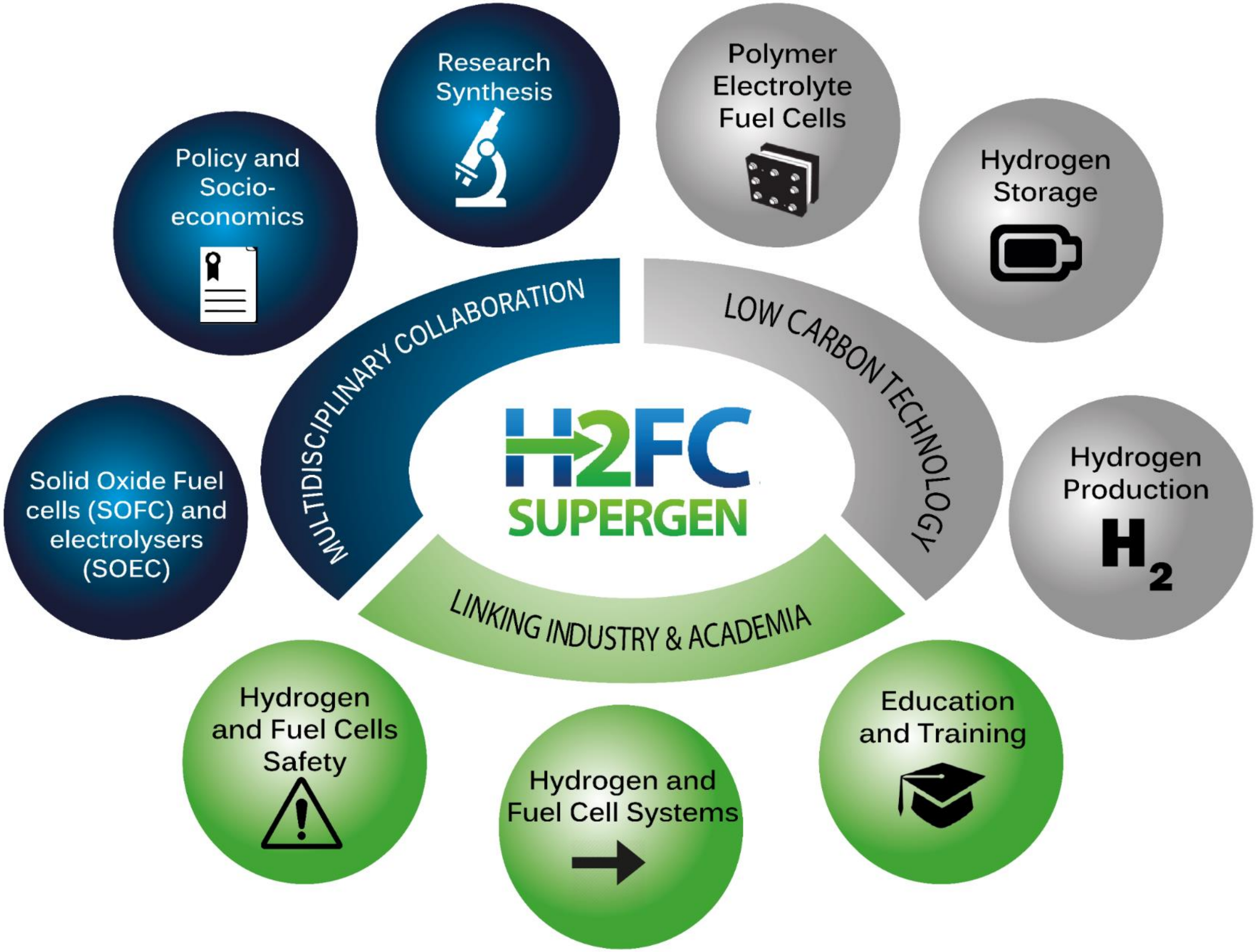

Four evidence based White Papers

To inform key stakeholders, especially policy makers, of the roles and potential benefits of hydrogen and fuel cell technologies for meeting UK energy objectives.

Launched at the London City Hall in March 2017

low-carbon heat | **energy security** | **future energy systems** | **economic impact for the UK**

Methods

1. Reviews of the technical, academic and commercial literature.

2. Engagement with core industry stakeholders.

3. Targeted analyses (e.g. comparative analysis of heating technologies complemented by scenario building using **UK Times Model**)

UK CO_2 reduction Targets (compared to 1990 levels):

- 80% CO_2 reduction by 2050
- 50% reduction by 2025 and 57% by 2030.

Decarbonising Heat...

Demonstration Studies

Hy4House

HyDeploy (Keele Uni.)

Liverpool Manchester Cluster

H21 Leeds City Gate Study

Hydrogen Upstream of the meter

£10m NIC award to GDNOs led by NGN

Hy4Heat

£25m BEIS research and Innovation Programme

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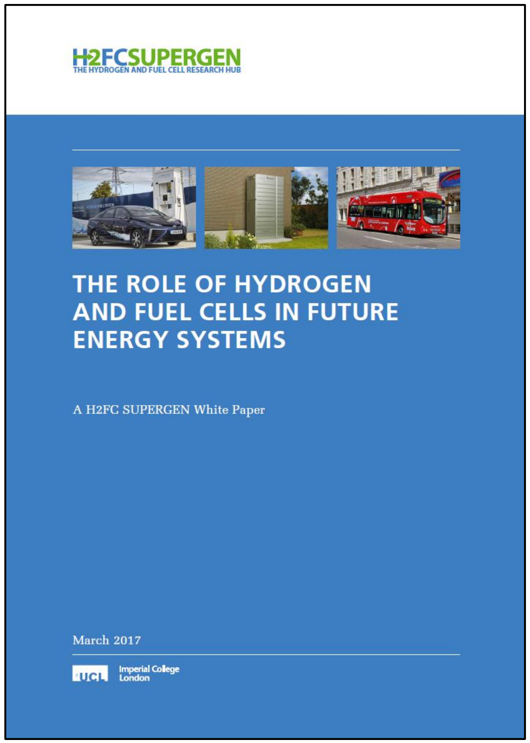
Future energy systems



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THE ROLE OF HYDROGEN AND FUEL CELLS IN FUTURE ENERGY SYSTEMS

A H2FC SUPERGEN White Paper

March 2017

UCL Imperial College London

* Examine the potential contribution of hydrogen and fuel cell systems to:
  * Transport.
  * Heat.
  * Electricity.
* Consider the infrastructure requirements.
* How might a transition to these systems occur?

Concludes that hydrogen and fuel cells:

* are too important to neglect;
* make decarbonisation easier; and,
* need greater policy visibility.

Imperial College London

UCL

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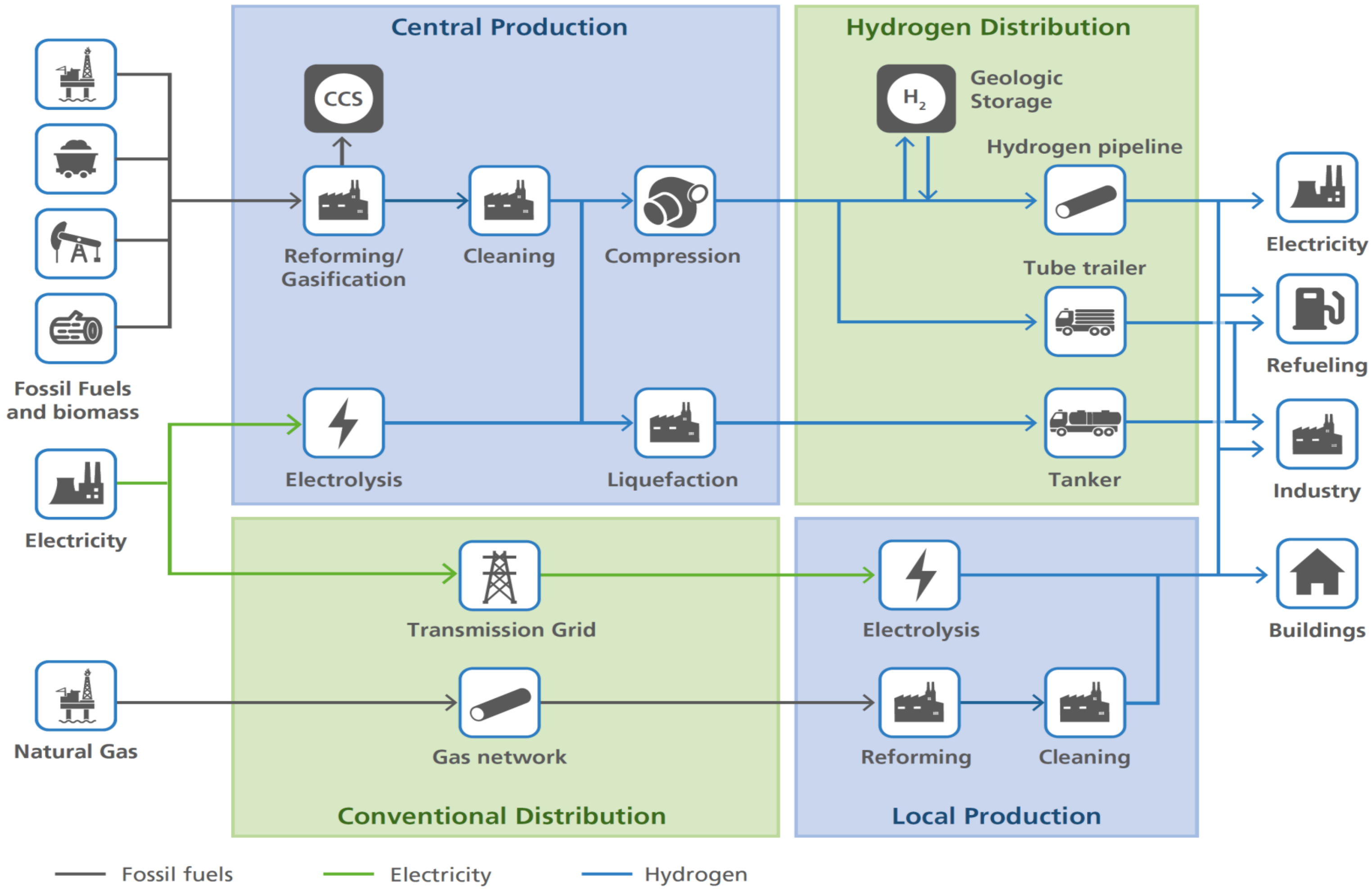
H2FC Infrastructure

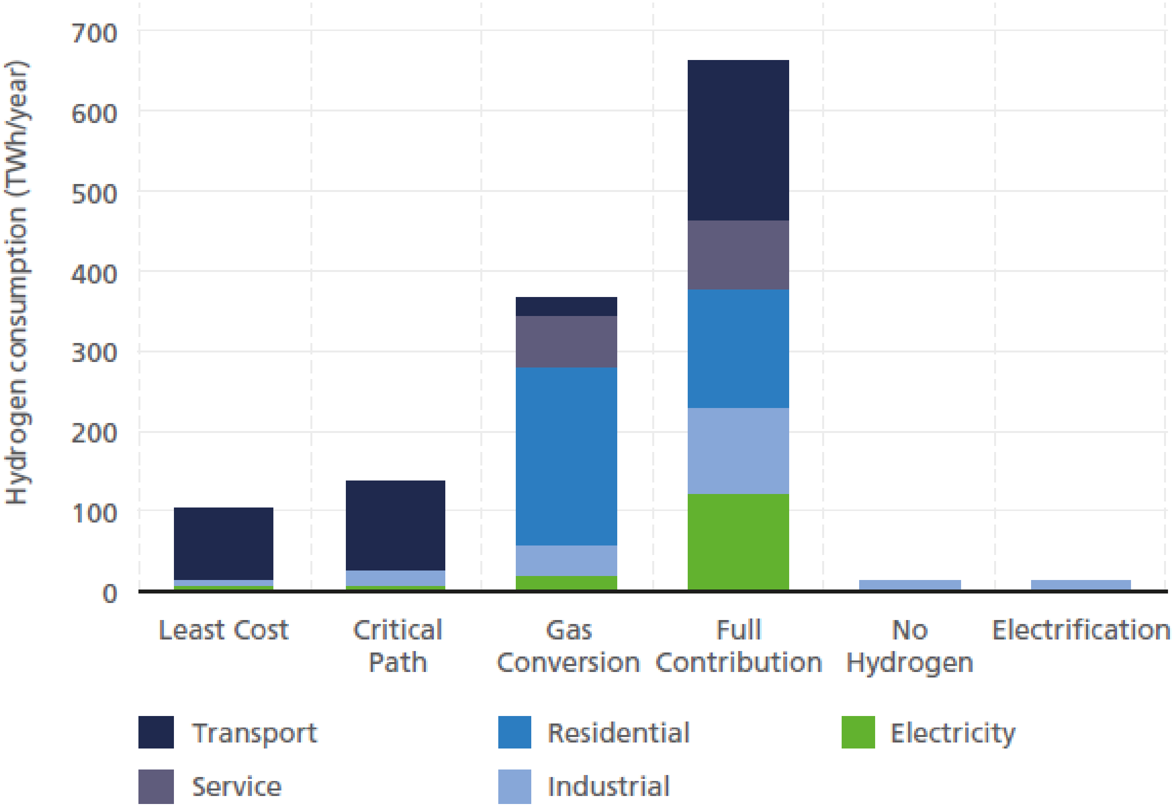


Scenarios

* **Least Cost:** the lowest-cost method of achieving the GHG target based on input assumptions.
* **Critical Path:** the hydrogen option is kept open to 2030 through small investments in infrastructure and road vehicles; deployment ramps up in 2050 for strategically important end uses (transport and electricity).
* **Gas Conversion:** gas networks are converted to deliver hydrogen; homeowners choose between low-carbon heating and transport technologies primarily on cost.
* **Full Contribution:** hydrogen is taken up across the economy; hydrogen boilers and hybrid heat pumps heat most houses by 2050; almost all road vehicles use fuel cells; substantial contributions from hydrogen in industry and electricity generation as well.
* **No Hydrogen:** a counterfactual scenario that is the same as Least Cost, except that no hydrogen technologies are available.
* **Electrification:** a counterfactual scenario with widespread electrification of end-use technologies that relies primarily on renewable generation.

Hydrogen consumption by sector, in the six scenarios to 2050

Targeted analyses using **UK Times Model**



Least Cost: the lowest-cost method of achieving the GHG target based on input assumptions

Critical Path: deployment ramps up in 2050 for strategically important end uses (transport and electricity).

Full Contribution: hydrogen is taken up across the economy; 50% of end-use demand is met by hydrogen in 2050

No Hydrogen: a counterfactual scenario that is the same as Least Cost

Electrification: a counterfactual scenario with widespread electrification of end-use technologies that relies primarily on renewable generation.

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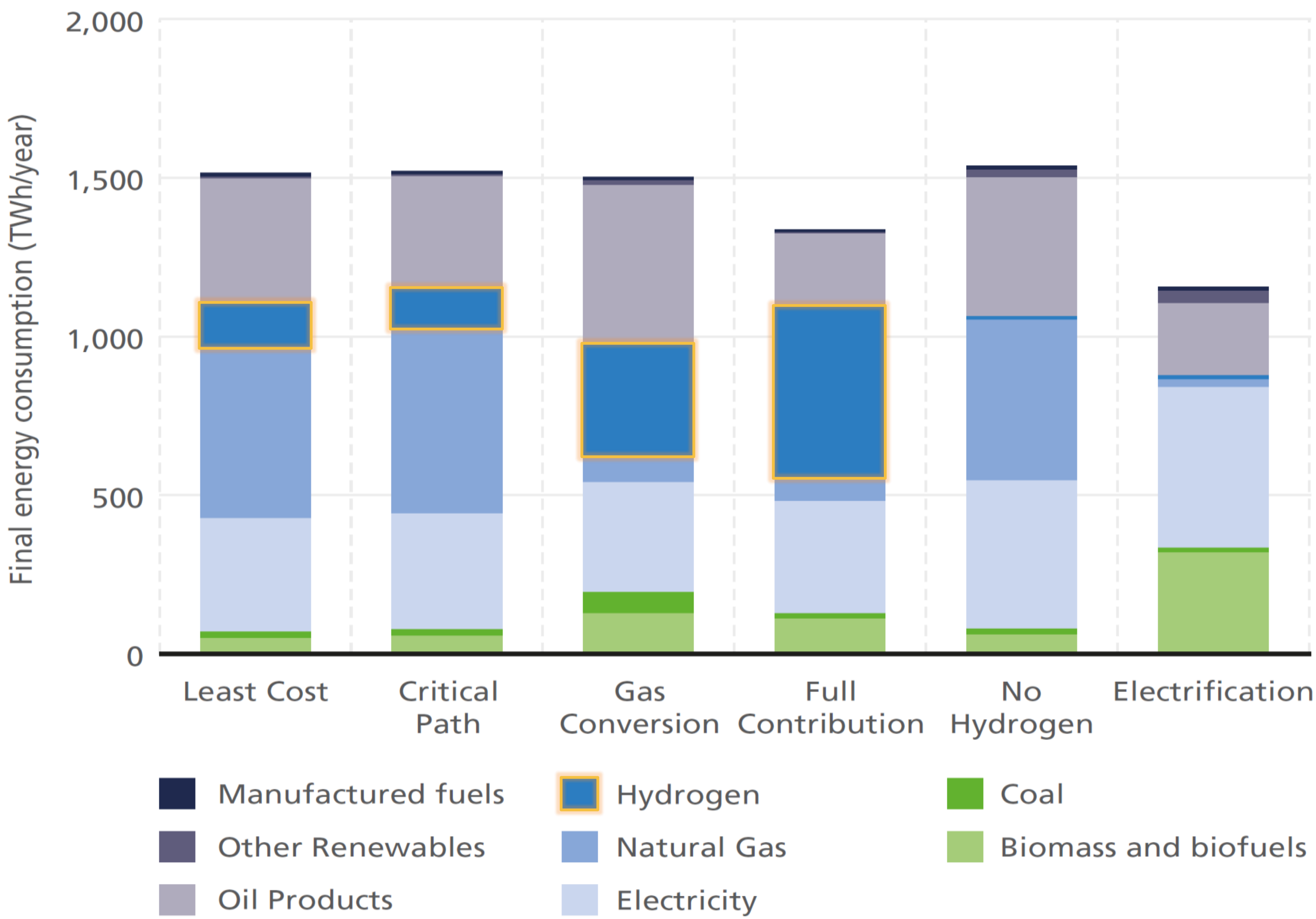
Final UK energy consumption in 2050, in the six scenarios



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Energy conversion costs for different scenarios

Table S2 **Total discounted costs of the energy systems in each scenario.**

Scenario	Basic scenario	No BECCS	No CCS
Least Cost	1.0	1.8	2.0
Critical Path	1.2	2.0	2.1
Gas Conversion	1.5	2.2	2.6
Full Contribution	2.3	2.6	3.0
No Hydrogen	1.1	2.2	2.3
Electrification	7.0	7.0	7.0

1/10 of final energy consumption from H2

for strategically important end uses

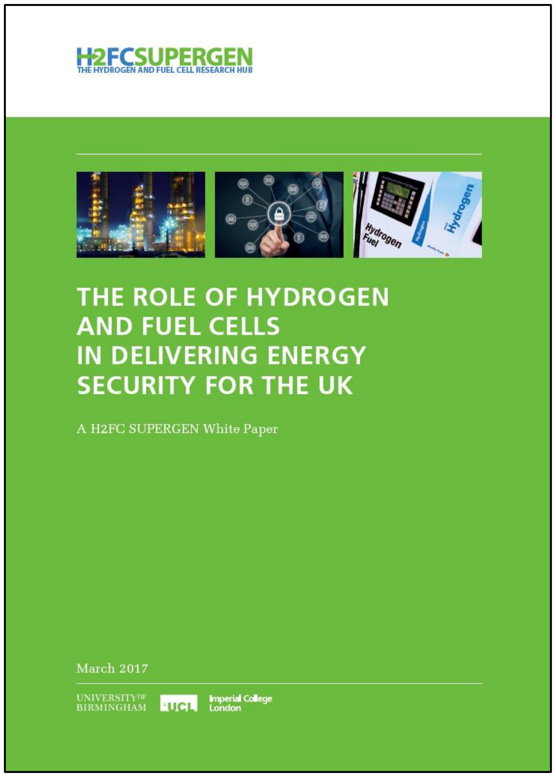
gas networks converted to deliver H2

H2 ½ of final energy consumption from H2

Mostly electrical

All costs are relative to the difference between the Least Cost scenario cost and the cost of an unconstrained reference scenario with no GHG emission targets. The Least Cost scenario therefore has a cost = 1. BECCS is bioenergy with carbon capture and storage (CCS).

Energy security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THE ROLE OF HYDROGEN AND FUEL CELLS IN DELIVERING ENERGY SECURITY FOR THE UK

A H2FC SUPERGEN White Paper

March 2017

UNIVERSITY OF BIRMINGHAM UCL Imperial College London

* How might hydrogen and fuel cells affect energy security in the UK energy system? Can they improve it? Would they worsen it?

Conclusions:

* Using hydrogen would not greatly change energy security, as measured by various indices – and the diversity of the energy system could increase.
* Using hydrogen could reduce the impacts of volatile energy import prices.
* The resilience of the UK electricity system could be increased by reducing the impacts of infrastructure damage (by natural incidents as well as malevolent interference).

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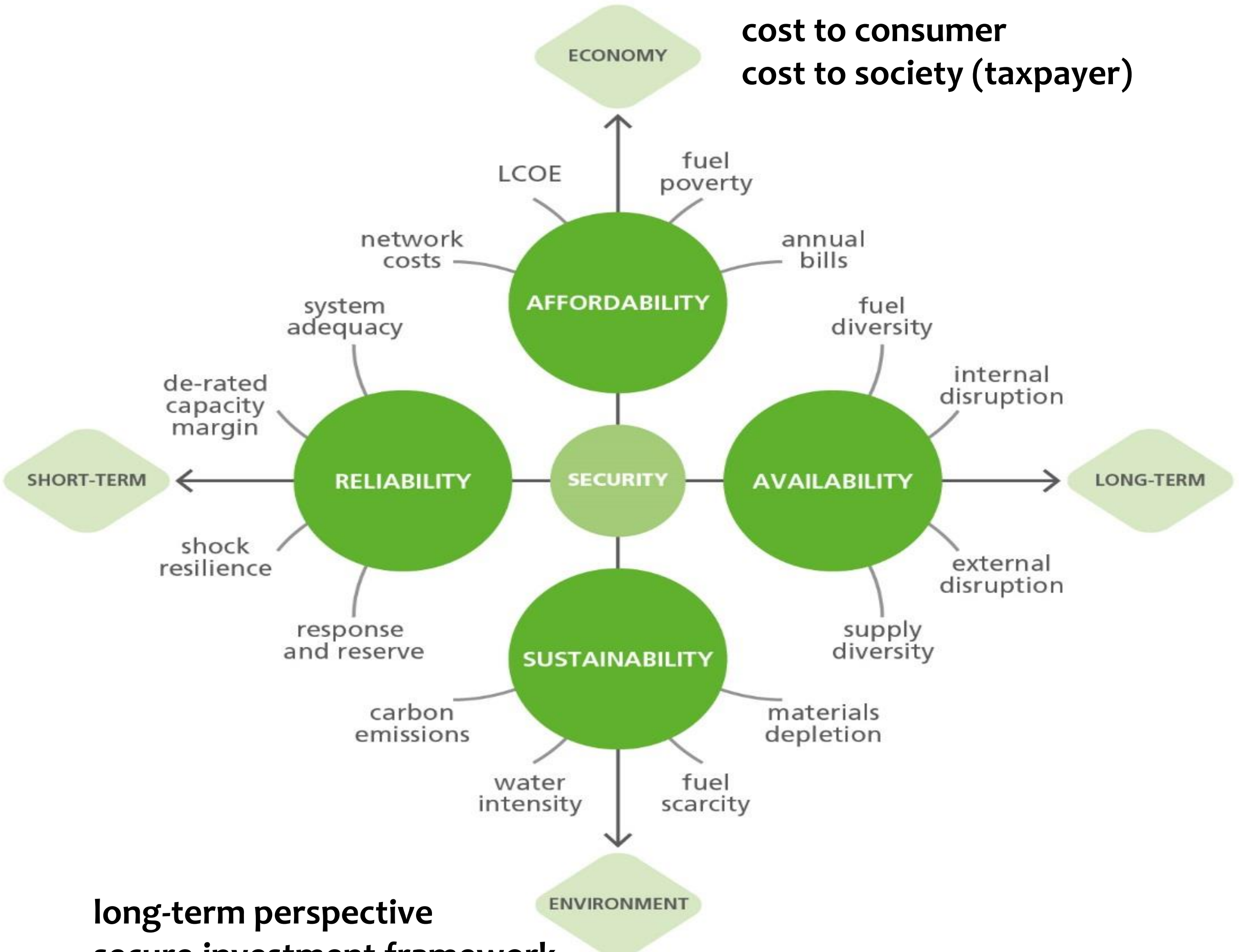
Energy Security Definition(s)

cost to consumer
cost to society (taxpayer)

resilience
robust to
incidents



robustness
long-term
stability

long-term perspective
secure investment framework

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Cost to increase diversity and resource independence in 2050

	Base	High diversity	Independence	High diversity and independence
Full contribution	2.3	2.3	6.0	6.3
Critical path	1.2	1.2	4.8	5.0
No hydrogen	1.1	1.2	4.8	5.0

All costs are relative to the smallest increase in costs required to meet the UK 80% GHG reduction target in 2050 in an unconstrained scenario in the UK TIMES Model (UKTM), relative to the reference scenario with no GHG targets. So this unconstrained scenario has a cost = 1.0.

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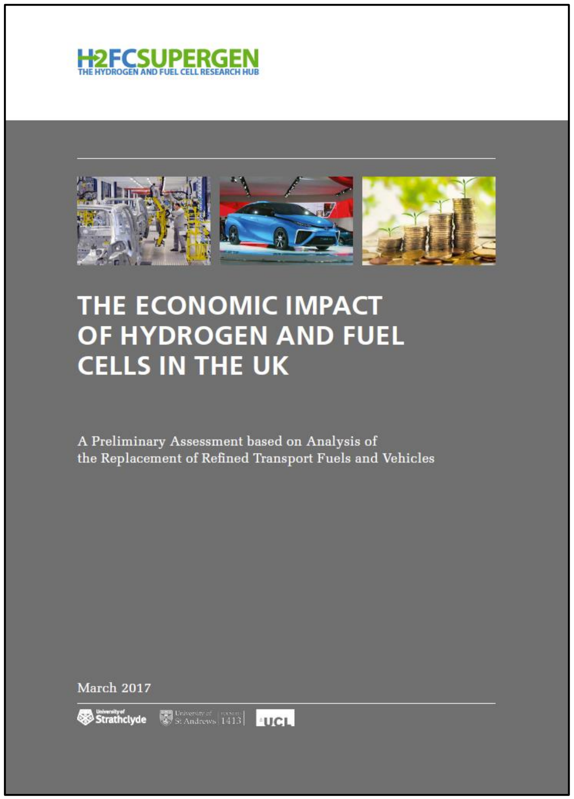
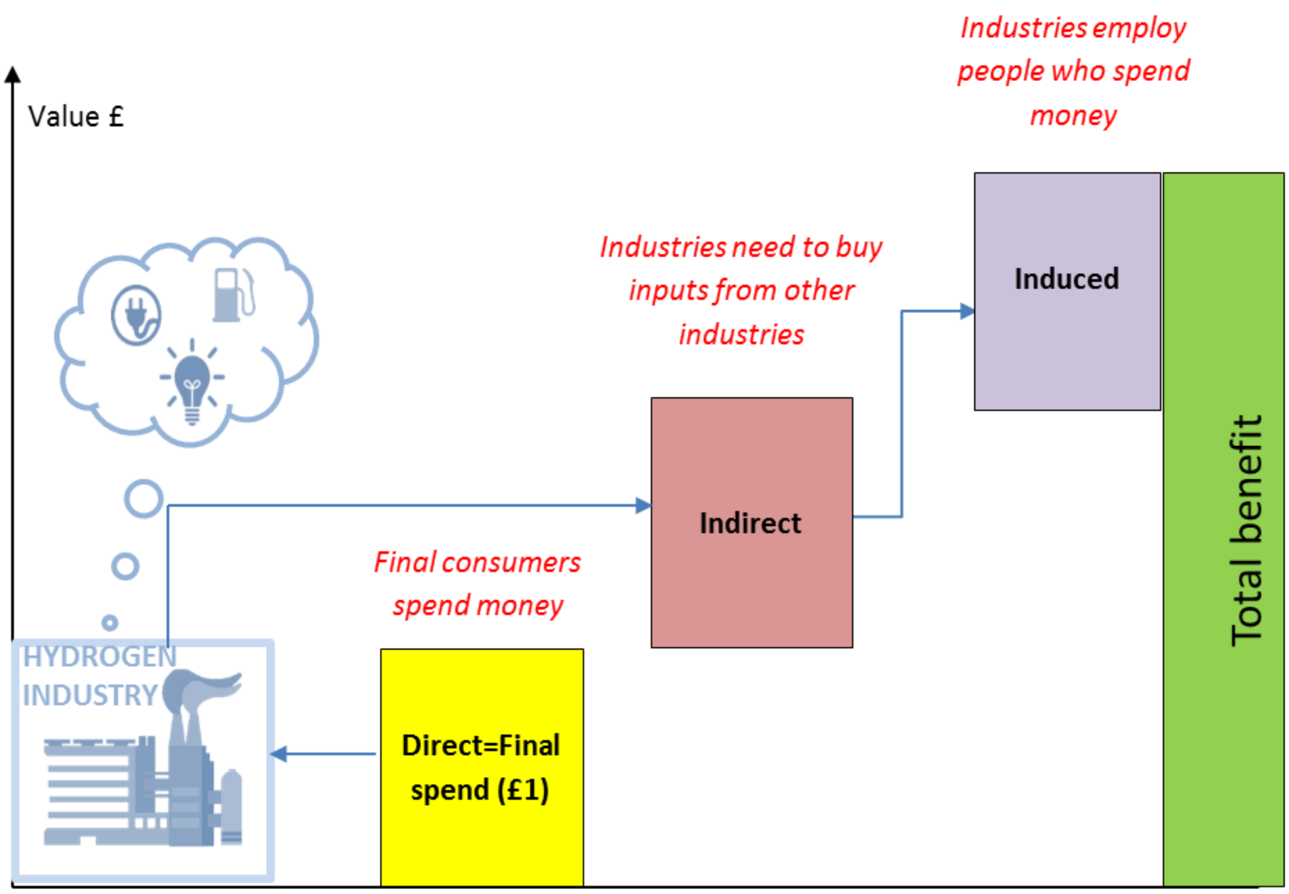
Economic Impacts



* An early assessment of the scale and type of impact hydrogen and fuel cell technologies could have on the UK macro-economy
* Uses **input-output modelling** to examine economy-wide impacts of building new supply chains for these technologies and reducing supply chains for incumbent systems.
* Considers economic (£m) and employment impacts (with **Consumer Road Transport as an exemplar**)
* Wider issues such as skills and industrial clusters are also examined.
* This is a preliminary study – there is much scope to develop the methodology to examine economic implications of energy technologies and an industrial strategy in the future.

Input-output - Multiplier Diagram



Relative values (UK) – Hydrogen

You are a potential hydrogen supplier

- We burn hydrogen for heat (assume 100% conversion efficiency)
- Apply approximate fuel cell conversions (losses) to generate relative values for electricity production and transport applications

That gives a modified *hydrogen value ratio set* of:

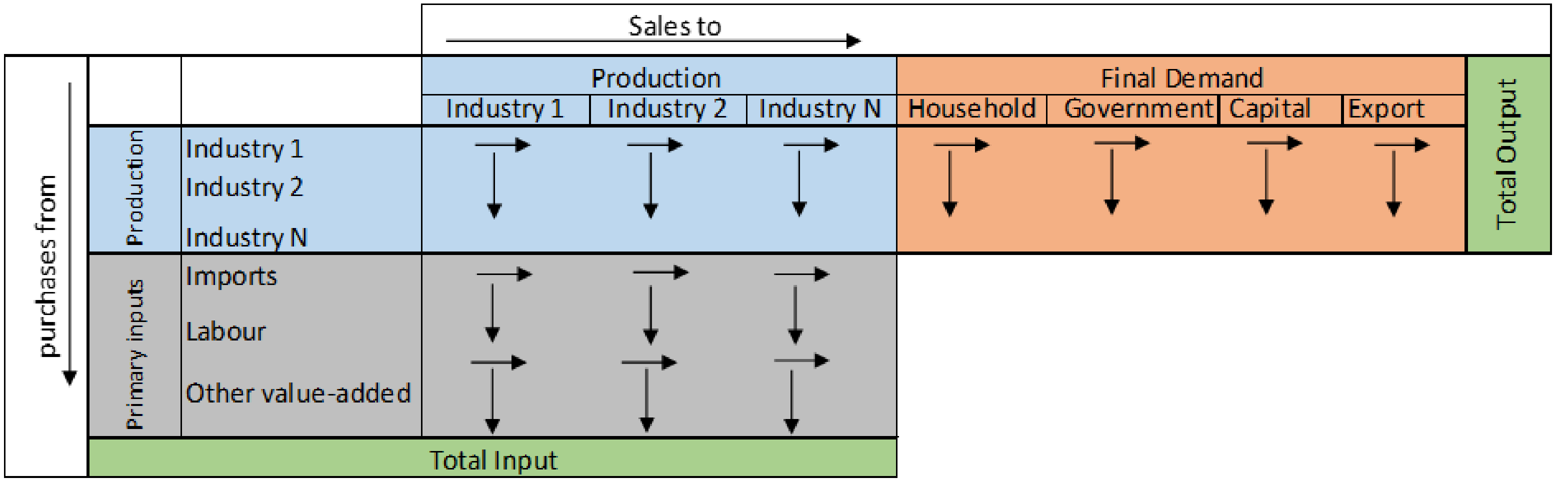
	Heat	Electricity	Transport
Cost of Energy (based on efficiency of device)	4.18p /kWh	13.86p /kWh	41p /kWh
Relative H2 value	1	1.6	3.9

Based on what you know consumers expect to pay for heat, electricity and transport,

In which market space are you most likely to make a good margin?

Not indicative of what H_2 might cost

Approach: input-output modelling



- Input-output data are produced as part of the UK National Accounts (ONS 2016), under United Nations System of National Accounts (SNA 1993).
- The UK (industry by industry) input-output tables (2010): is a matrix describing the structure of the economy in a given year in terms of 103 industries (identified by the Standard Industrial Classification, SIC 2007).

Headline message of input-output modelling

A significant move away from current UK use of refined fuels in private transport towards hydrogen can yield a valuable increase in GDP and employment

- The likely gains will come not only from the production and distribution of hydrogen in the UK but also from the ***range of service sector activities***, including finance, involved in a potentially ***strong domestic supply chain***.

- Key driver of findings: ***the current supply chain for petrol and diesel is highly import-intensive***.

Where will H_2 come from?

- Importance of ***domestic (UK) supply chain linkages*** in delivering economic expansion through multiplier effects

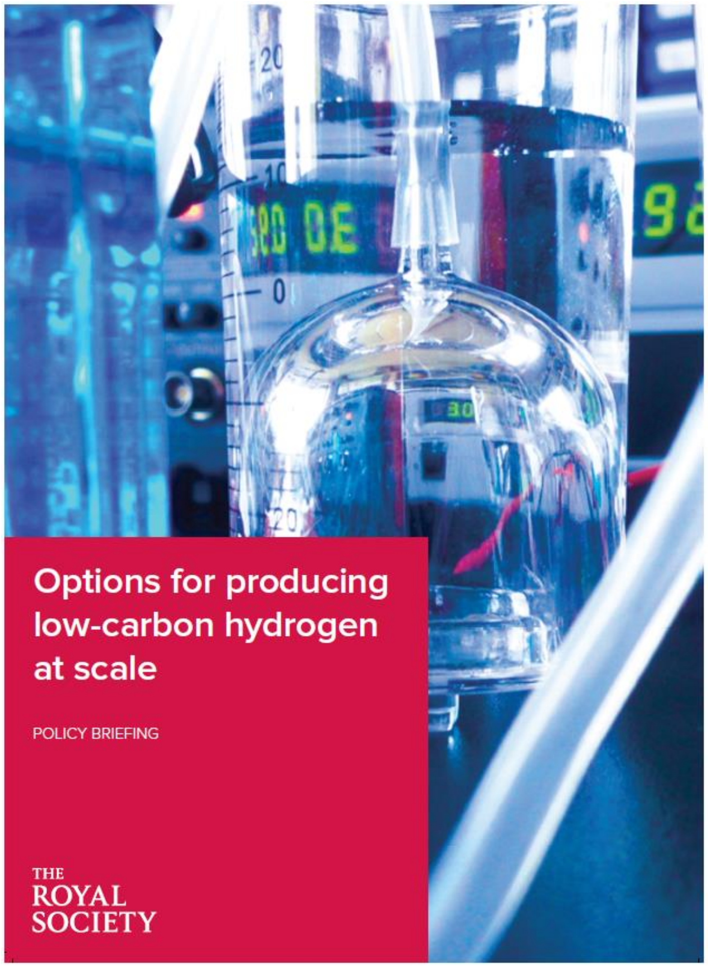
- ***If*** hydrogen supply could ***replicate the strong domestic upstream supply linkages of the current UK gas and electricity supply sectors***, opportunities for economic expansion through a hydrogen transport economy

- However, much will depend on the ***continued role of fossil fuel extraction*** from the UK oil and gas extraction industry

- Attention in development of the skills base in UK **service industries**

- Potential additional impacts from private and public investment targeted at R&D, construction etc., but impacts may be time-limited (as opposed to on-going operational)

Recent publications



The role and status of hydrogen and fuel cells across the global energy system

Iain Staffell[a], Daniel Scamman[b], Anthony Velazquez Abad[b], Paul Balcombe[c], Paul E. Dodds[b], Paul Ekins[b], Nilay Shah[d] and Kate R. Ward[a].

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Abstract

Hydrogen technologies have experienced cycles of excessive expectations followed by disillusion. Nonetheless, a growing body of evidence suggests these technologies form an attractive option for the deep decarbonisation of global energy systems, and that recent improvements in their cost and performance point towards economic viability as well. This paper is a comprehensive review of the potential role that hydrogen could play in the provision of electricity, heat, industry, transport and energy storage in a low-carbon energy system, and an assessment of the status of hydrogen in being able to fulfil that potential. The picture that emerges is one of qualified promise: hydrogen is well established in certain niches such as forklift trucks, while mainstream applications are now forthcoming. Hydrogen vehicles are available commercially in several countries, and 225,000 fuel cell home heating systems have been sold. This represents a step change from the situation of only five years ago. This review shows that challenges around cost and performance remain, and considerable improvements are still required for hydrogen to become truly competitive. But such competitiveness in the medium-term future no longer seems an unrealistic prospect, which fully justifies the growing interest and policy support for these technologies around the world.

H2 & FC Uptake targets

Country	CHP		Fuel cell cars			Refuelling stations		
	2020	2030	2020	2025	2030	2020	2025	2030
Japan	1.4m	5.3m	40,000	200,000	800,000	160	320	900
Germany	–		100% ZEV[a] by 2040			400		–
China	–		3,000[b]	50,000	1m	100	300	1,000
US	–		0	3.3m	–	100[c]	–	–
South Korea	–	1.2 MW	10,000	100,000	630,000	100	210	520
UK	–		100% ZEV[a] by 2040			30	150	–

(a) Zero Emission Vehicle

Ref: The role and status of hydrogen and fuel cells across the global energy system, I. Staffell et al.

(b) Shanghai only

(c) California only

- UK in **top 10 countries** globally in terms of numbers of hydrogen and fuel cell publications
- **2nd** only to Germany in terms of **average citations per article.**

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Industrial Strategy Challenge Fund

- ISCF – Innovate have issued an EOI (closing date 18 April) inviting proposals on the potential future challenges to get support through the Industrial Strategy Challenge Fund

- Mission based innovation:

  Prof Marina Mazzucato (UCL)

- IEA Hydrogen Tasks:
  1) Market Deployment & Pathways to Scale
  2) Hydrogen in Industry and Buildings

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Thank you!

Download the four White Papers:

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