THE ROLE OF HYDROGEN AND FUEL CELLS IN FUTURE ENERGY SYSTEMS

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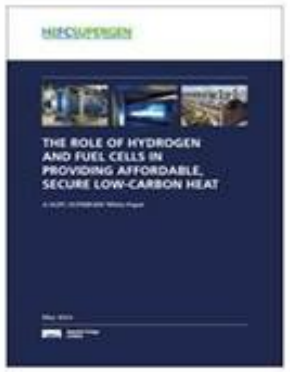
Aim of the White Papers

To commission 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.



Low Carbon Heat

Future Energy Systems

Energy Security

Economic Impact

Hydrogen Energy Carrier(s)

Achievement: zero emission energy vector (carrier)

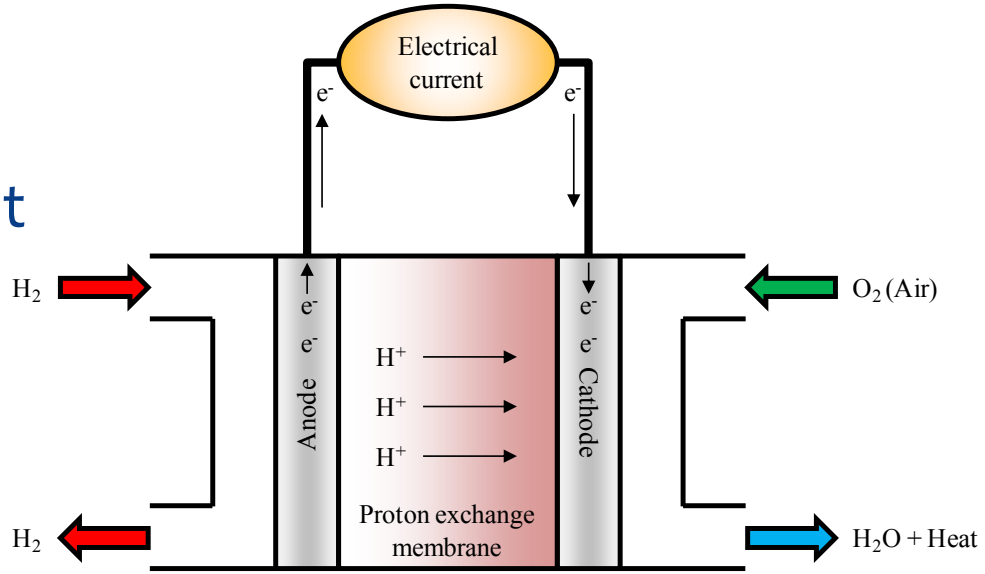
- abundant element in the world and the universe
- conversion product is only water
- zero emission fuel, if produced by zero-emission feedstock
- if burnt in a combustion engine or gas turbine will also emit NO_x
- safer in handling than many of today's fuels (e.g. petrol)
- can replace natural gas
- can be converted to Synthetic Natural Gas (SNG) or other synthetic fuels

Hydrogen to Energy: Fuel Cells

Achievement: reduction in energy demand due to improved efficiency

* not limited by the Carnot efficiency: upper limit of the efficiency of (thermal) power plants

* electrical efficiencies:
  - nuclear power station ▸ 33%
  - best coal fired power station at full power ▸ 52%
  - CCGT 400 MW ▸ 60%
  - fuel cell 2 kW ▸ 35 to 60%
  - fuel cell CCGT 100 kW ▸ 70%



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H2FC for Transport

* Fuel cell vehicles are now produced by major manufacturers
* Driving range and refuelling time match conventional vehicles
* Costs can achieve parity with alternatives by 2025–2030
* Fuel cell vehicles improve urban air quality by producing zero / near-zero exhaust emissions

H2FC for Transport

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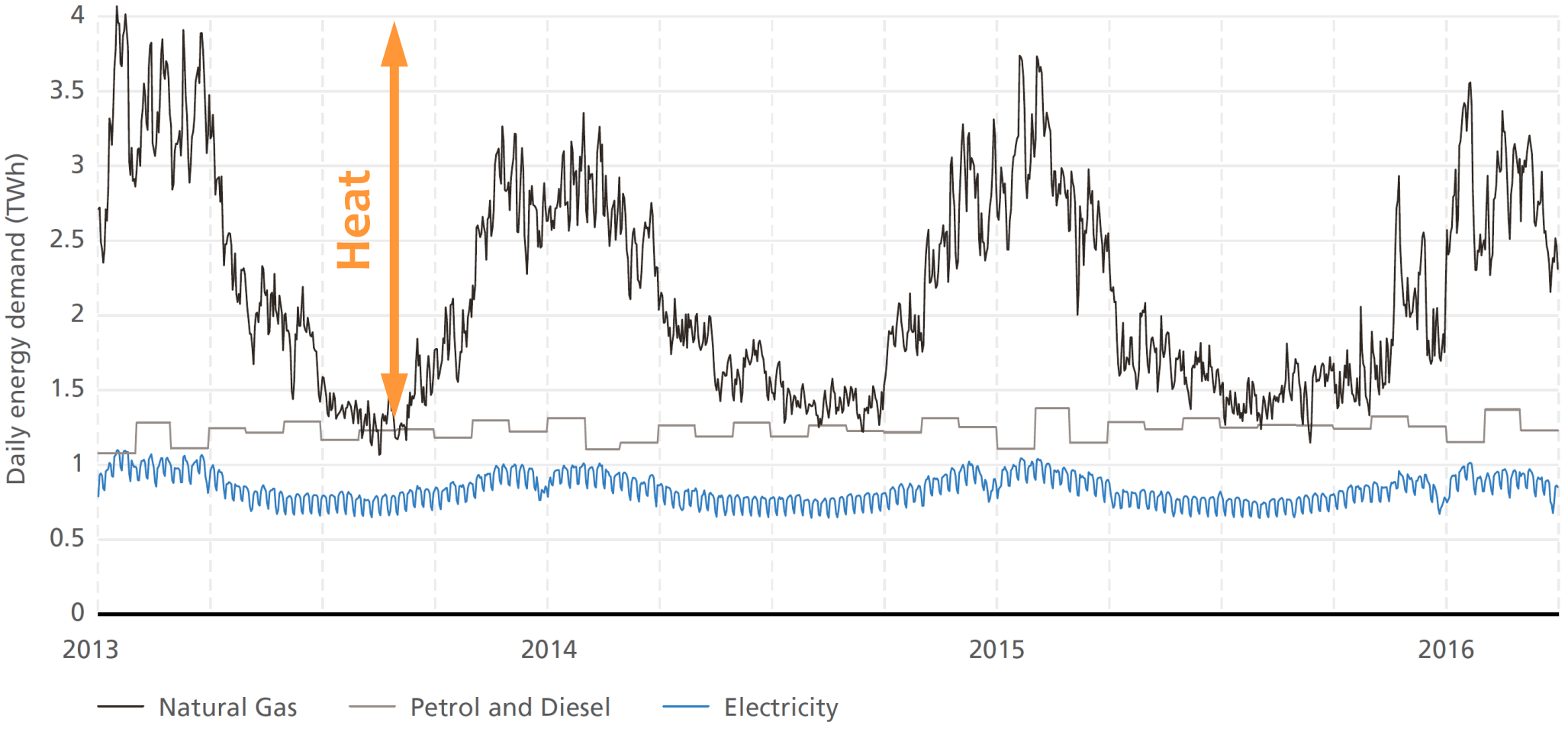
H2FC for Heat



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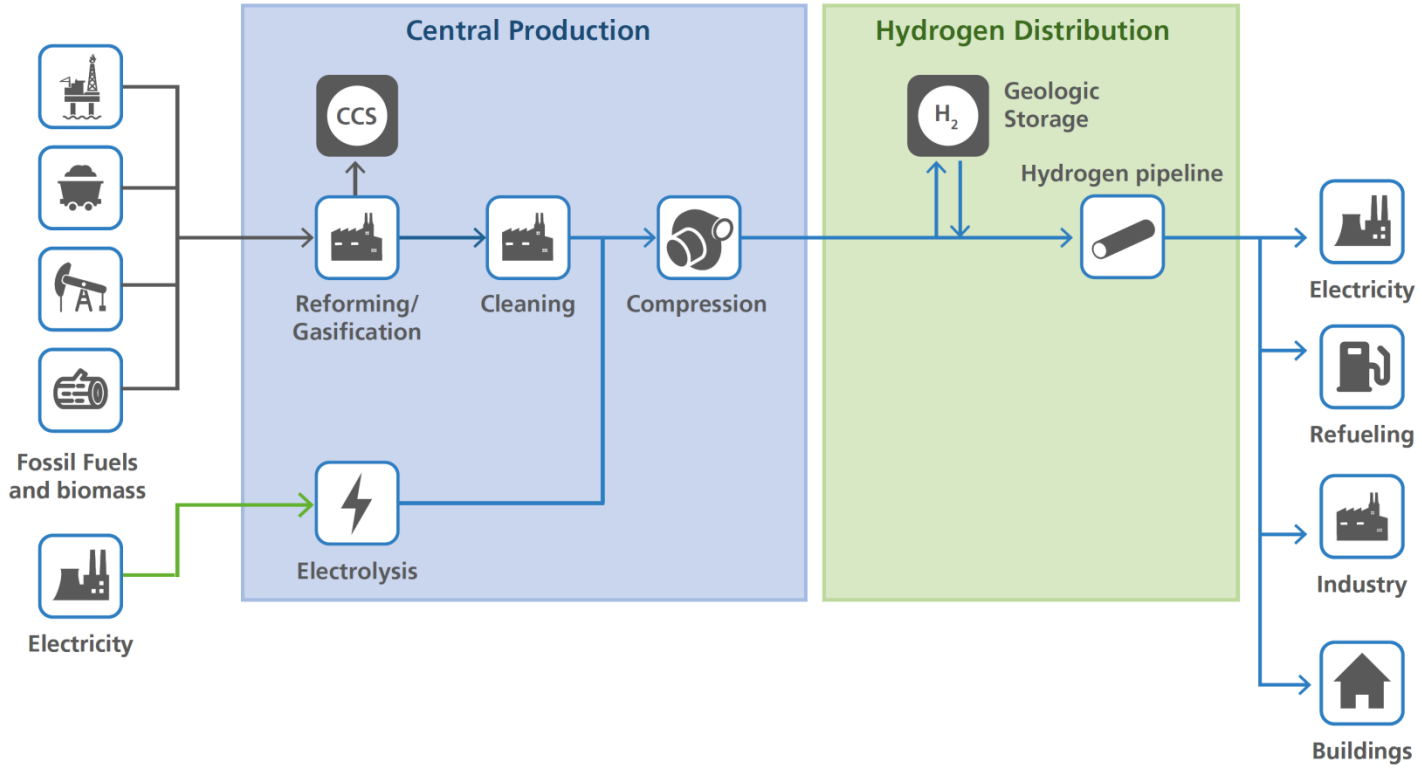
H2FC for Heat

* Decarbonising heat faces many challenges
* Fuel cell CHP can operate on today's natural gas network and later transition to hydrogen supply
* Hydrogen can decarbonise this network in the longer term – either in the shape of hydrogen or as SNG
* Households are accustomed to compact powerful heating systems, which could use hydrogen

H2FC for Electricity

* Hydrogen can support low-carbon electricity systems
* Fuel cells are controllable and offset electric heat pumps
* Power-to-gas gives large-scale, long-term storage
* Data centres, backup and households are major applications

H2FC Infrastructure



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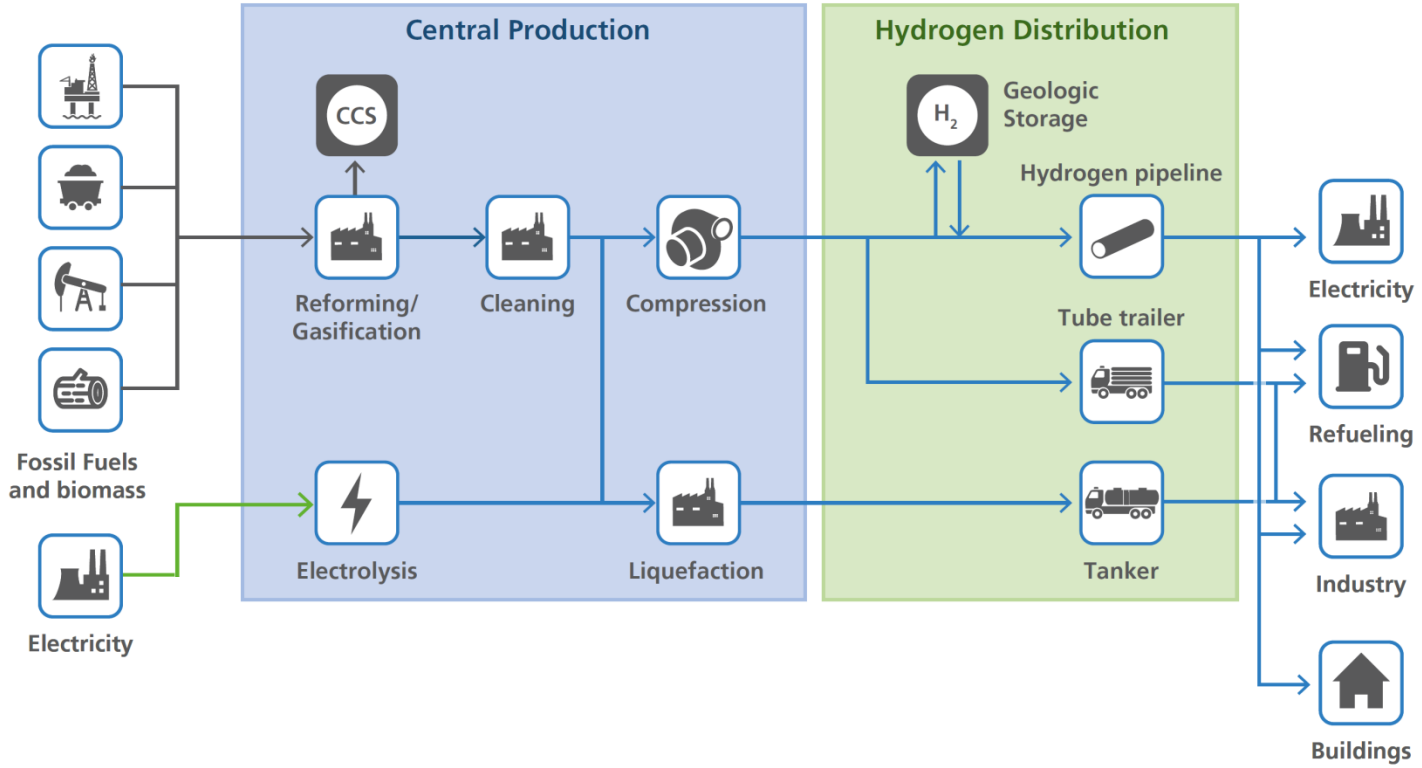
H2FC Infrastructure



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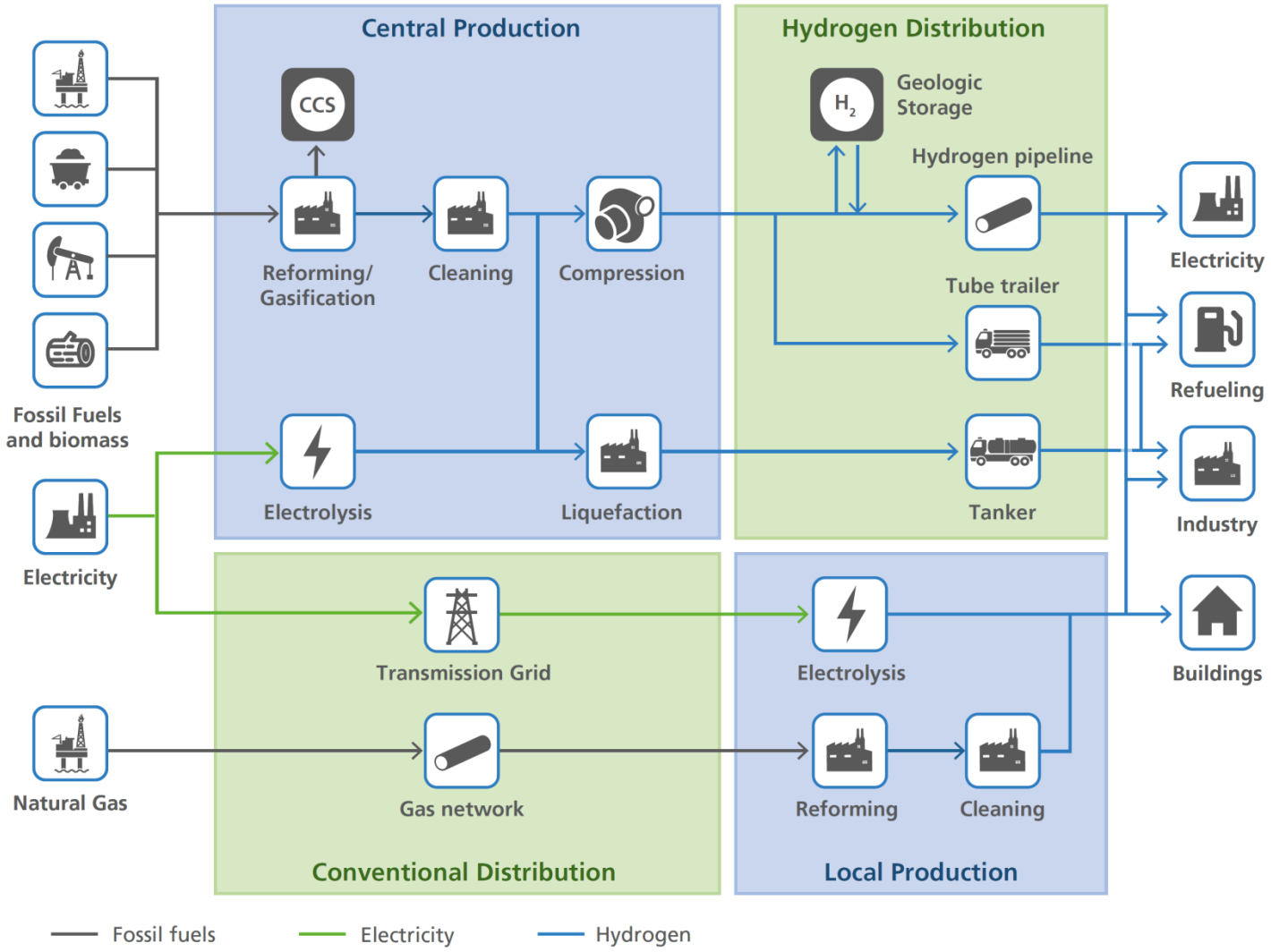
H2FC Infrastructure



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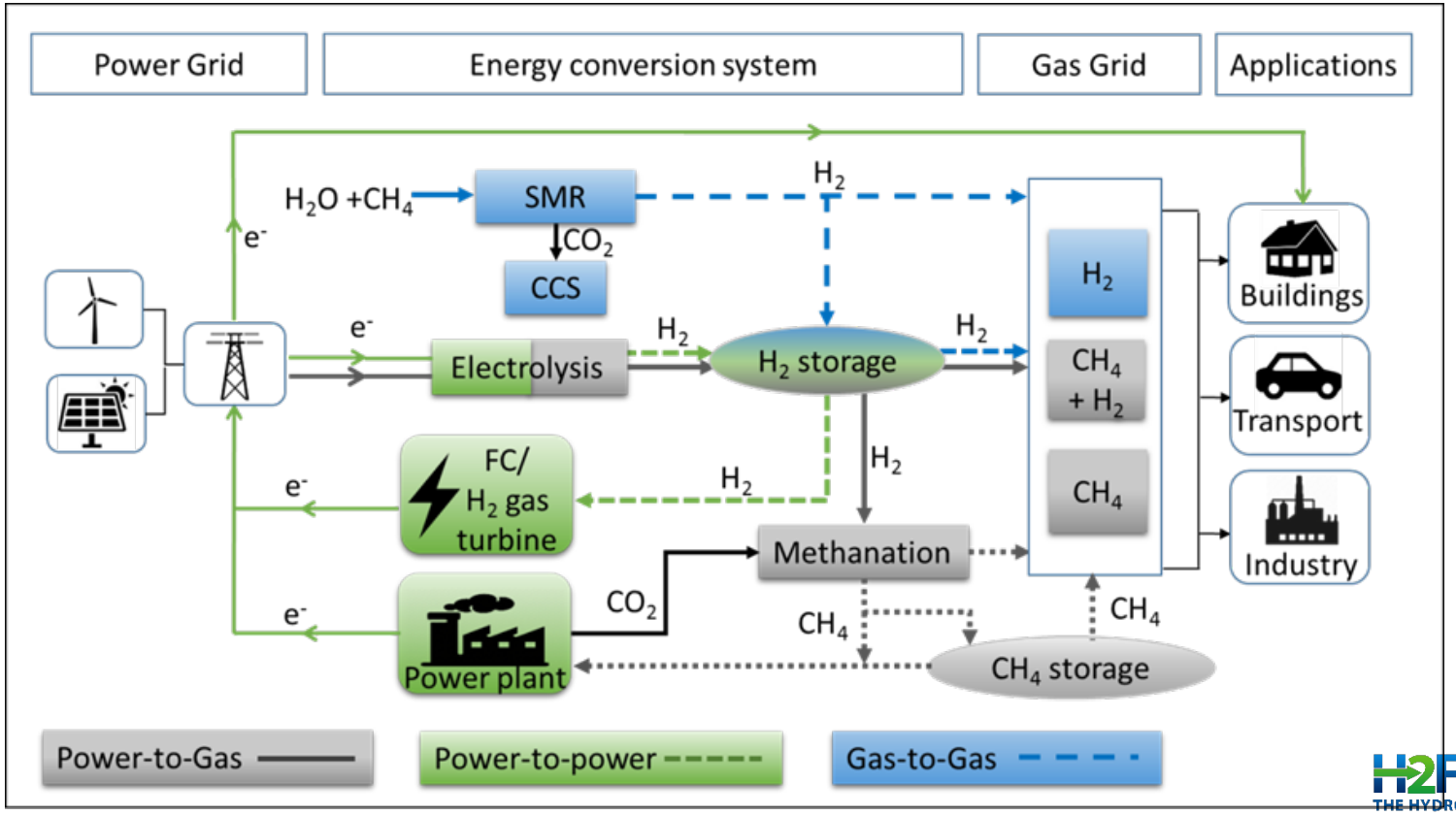
Linking Energy Sectors

Achievement: increasing flexibility and resilience of energy infrastructure

Fuel Cells and electrolysis as complementary technologies linking the electricity and gas markets (as well as transport fuels).
Provide balancing power for high renewable electricity systems.



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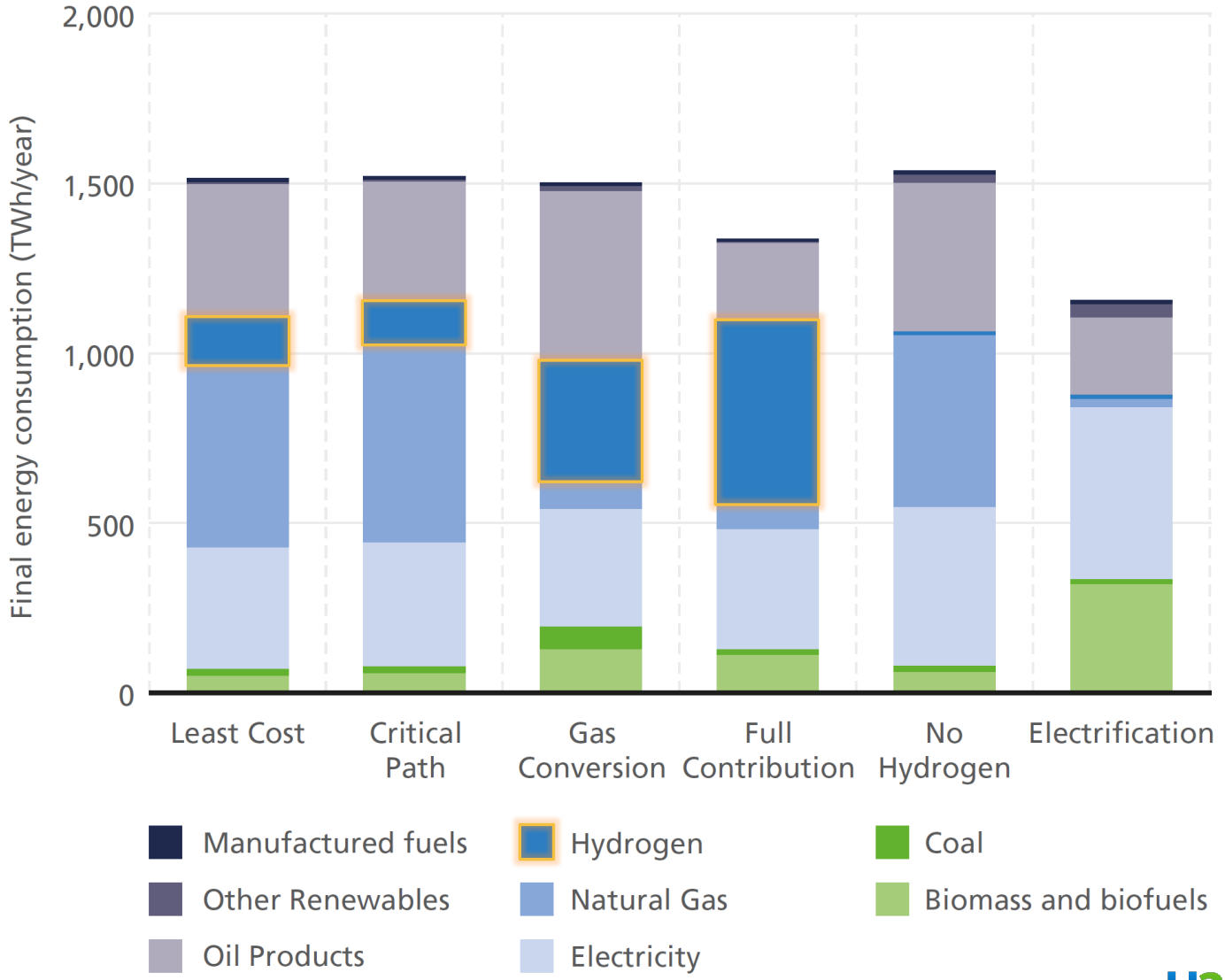
H2FC Scenarios for the UK



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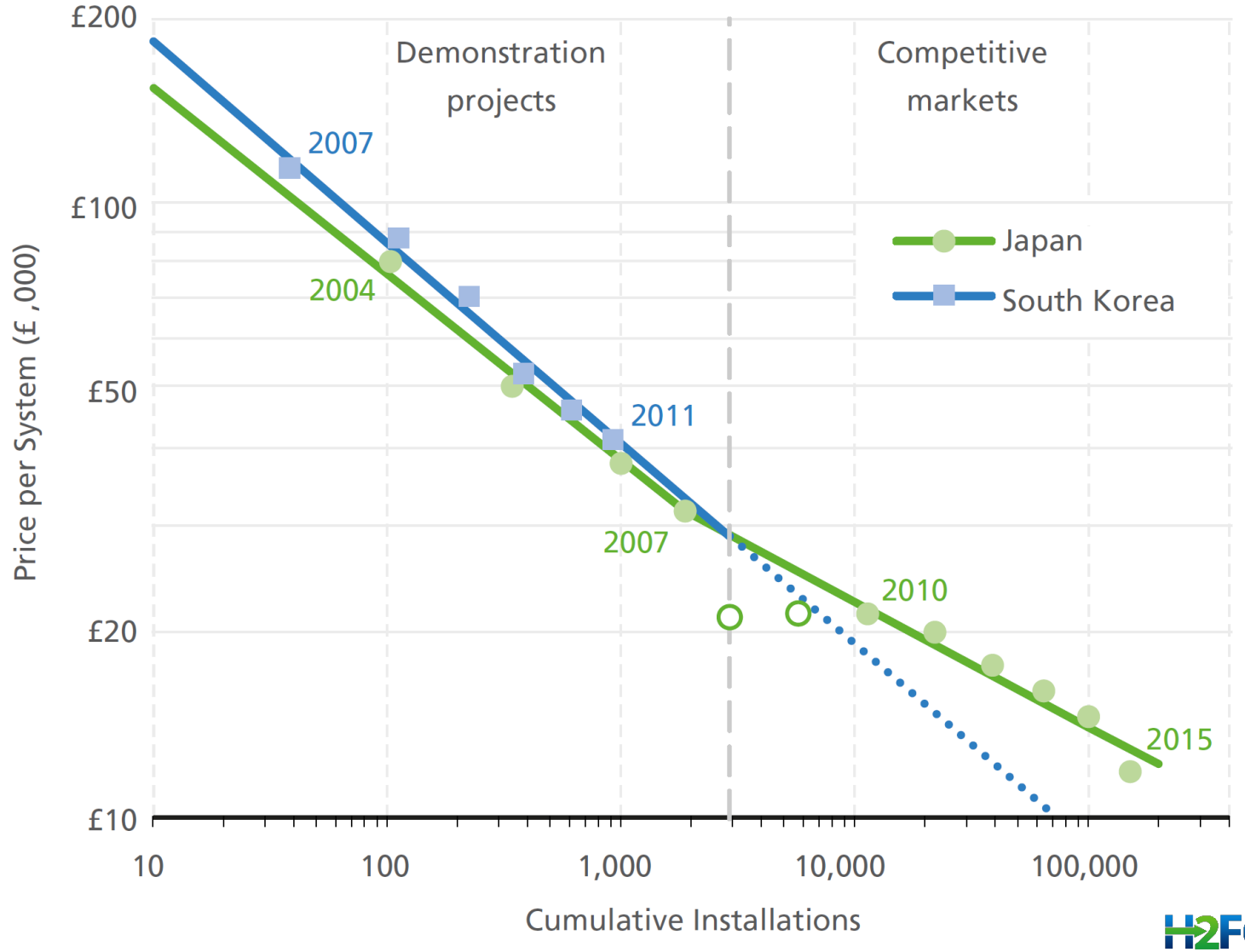
H2FC Policies and Drivers



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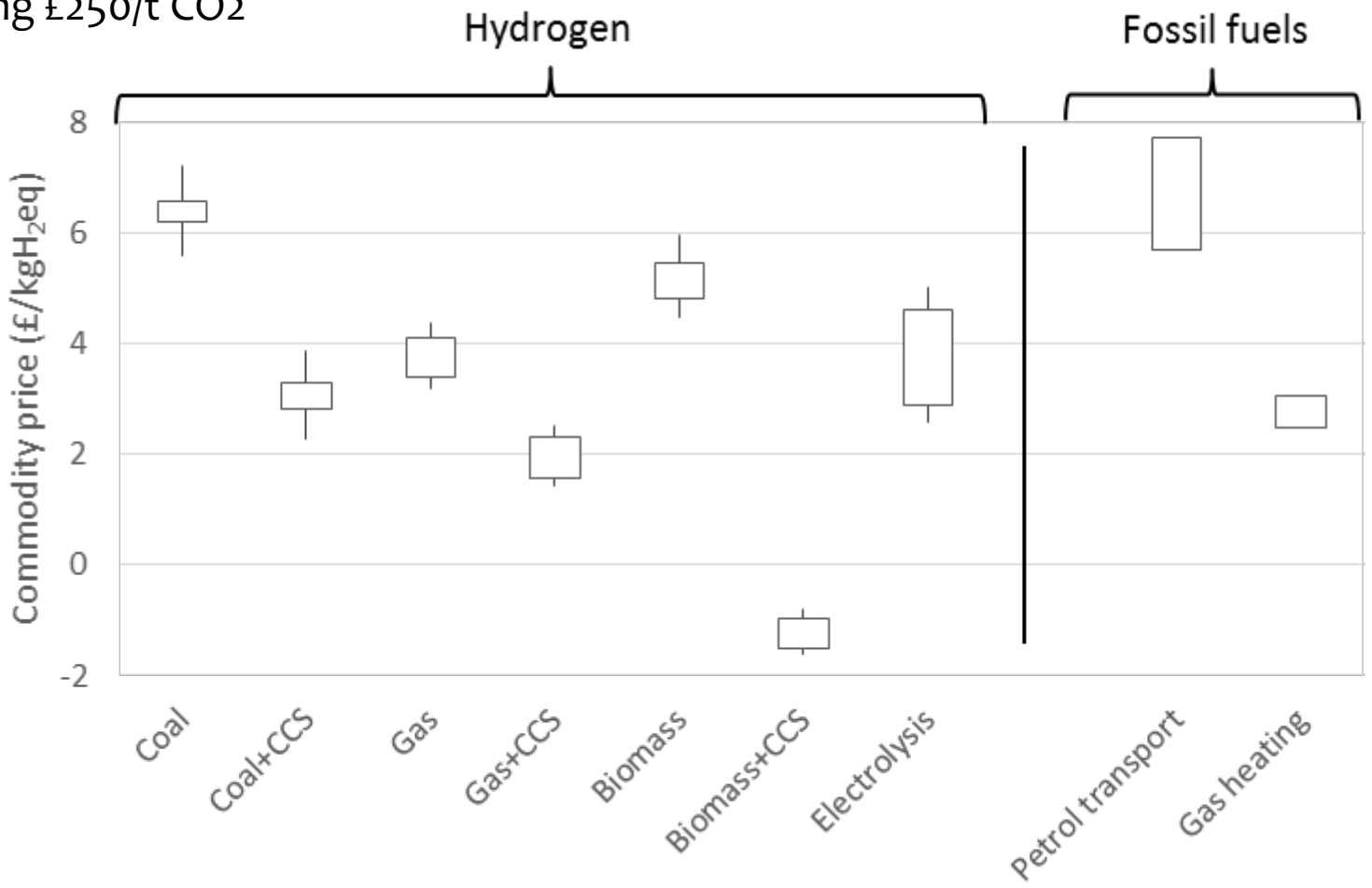
Hydrogen Cost Development

assuming £250/t CO2



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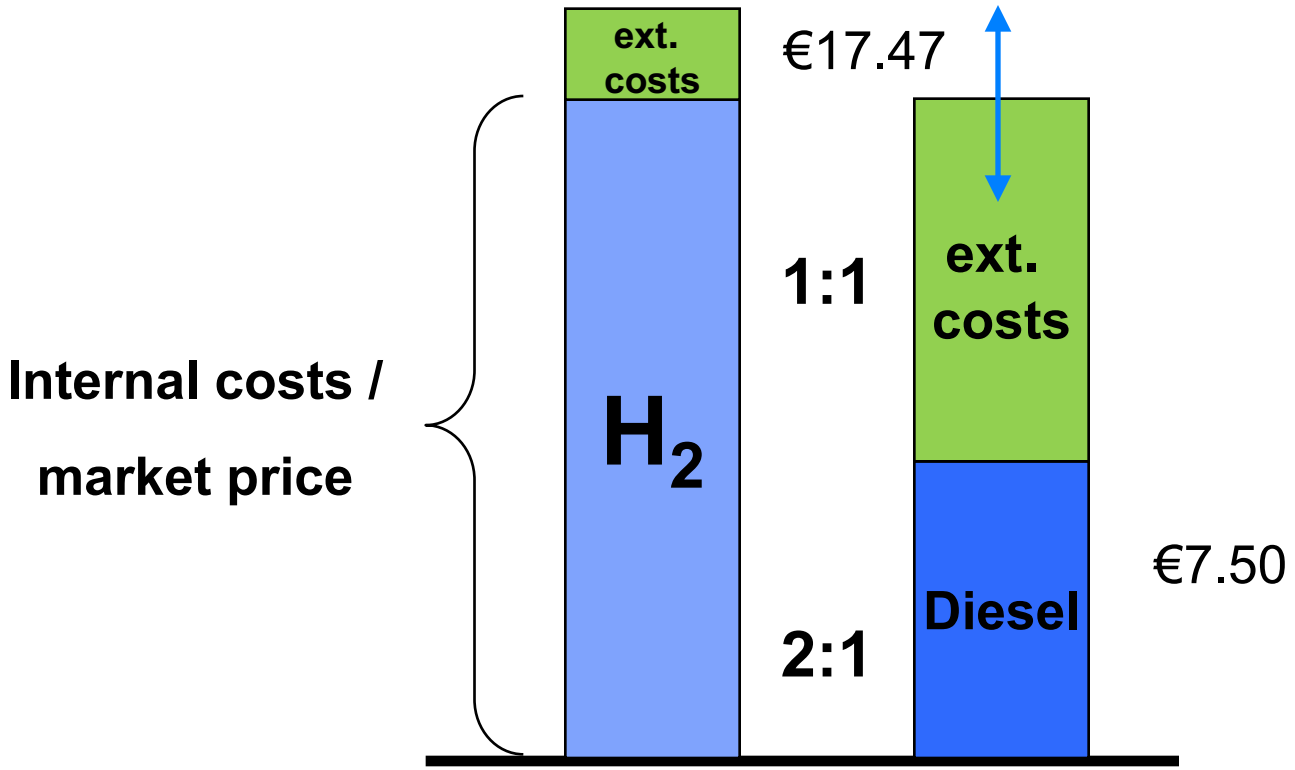
Pump Price vs. Societal Cost

* customer pricing of energy services largely excludes environmental and societal damages
* externalities:
  - environmental damages
  - health impacts, incl. smog
  - corrosive urban air impact on buildings
  - limitations to human habitat
* compensation for damages paid by state (taxpayer) or by the individual (health impacts)

Full Cost of Transport

‘polluter pays’ principle, sustainable allocation of cost



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H2FC Policy

	CHP	Vehicles	Refuelling
Japan	181,500	900 cars	78
Germany	~1,000	100 cars, 14 buses	22
China	n/a	90 cars, 40 buses	4
US	0.7 MW	331 cars, 33 buses	87
South Korea	177 MW	71 cars	7

Uptake to Sep 2016

	CHP	Vehicles	Refuelling
Japan	£500–1,400 per unit	£107m	£45m
Germany	€ 10,200 / kW	€8m for trains	€350m
China	?	£23–58k per vehicle	£500k per station
US	up to $3,000 / kW	$8k per vehicle $0.50 / gallon H_2	$100m in California
South Korea	$31m total	£20k per vehicle	?

Govt. support

H2FC Policy

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UK	~10	42 cars, 18 buses	14

Uptake to Sep 2016

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South Korea	$31m total	£20k per vehicle	?
UK	n/a	£2m for cars £2.8m for buses	£5m

Govt. support

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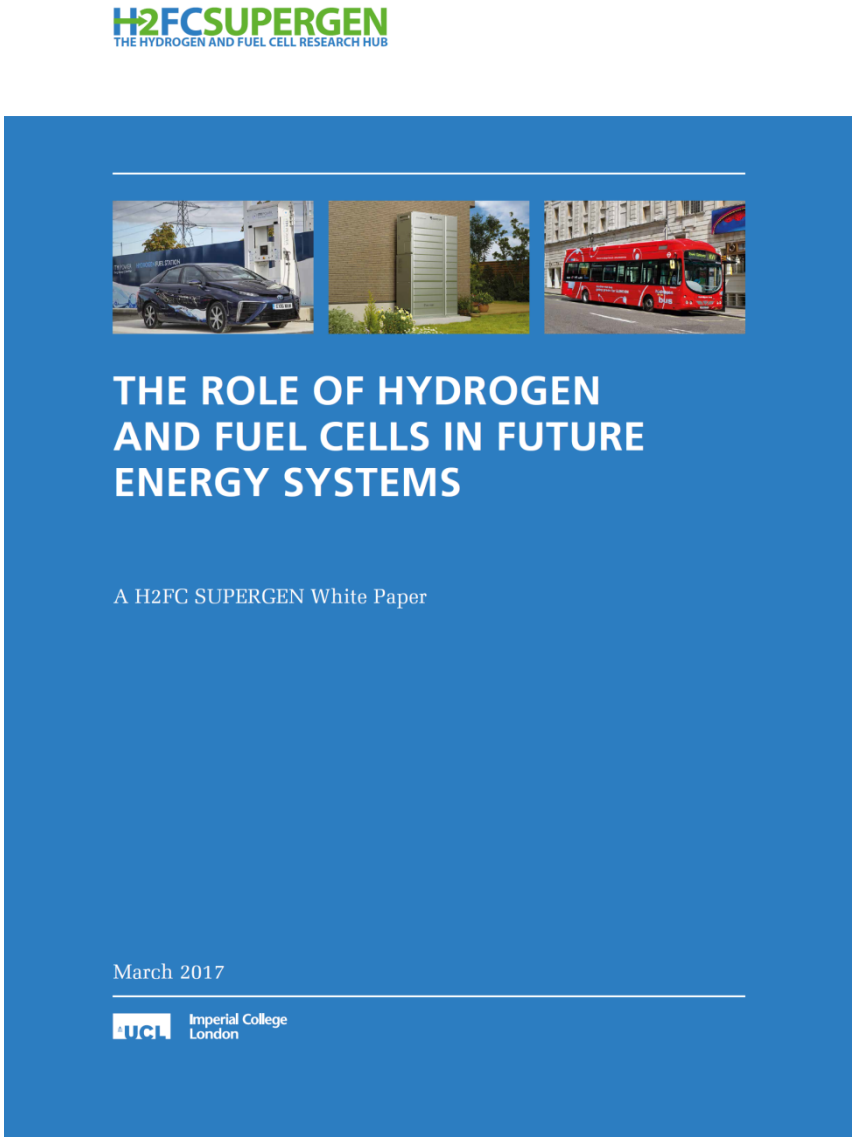
To recap…

Hydrogen and fuel cells are a key technology in:

* integrating large scale renewable energy
* reducing urban air pollution
* reducing energy import dependency
* increasing energy supply efficiency












Thank you for your attention!

Any questions?

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