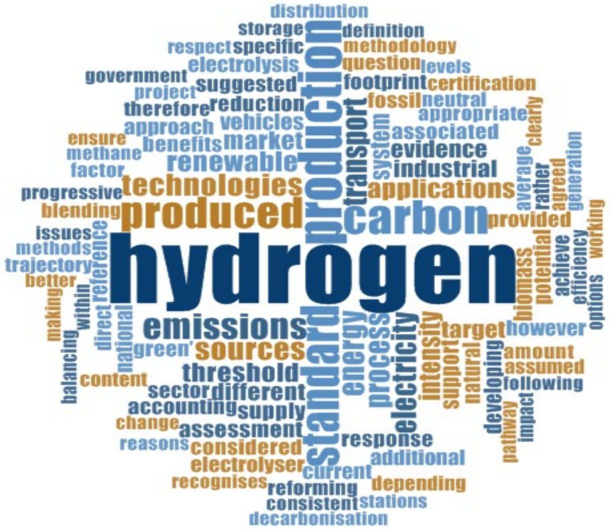
# Policy options for encouraging the deployment of green hydrogen and fuel cells

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22nd World Hydrogen Conference (WHEC 2018), 19th Jun 2018, Rio de Janeiro, Brazil

# Agenda

- What is green hydrogen?
- Why is hydrogen of interest for policy makers?
  - Economic growth drivers: Industrial strategy & employment
  - Environmental drivers: Air quality
  - Climate change drivers: Renewables and GHG Emissions
  - Energy security, reliability & flexibility
- Policy options for energy demand and generation
- Policy options for transport
- Conclusions

# What is green hydrogen? (No Universal Definition)

| Definition | Sources |
|---|---|
| Renewable hydrogen with an explicit mention to air pollution, energy security and global climate problems | NREL (1995) |
| Renewable hydrogen with an explicit mention to carbon intensity/reduction | Blieschwitz and Bader (2008); CertifHy (2016); Galich and Marz (2012); Gazey et al. (2012); AFHYPAC (2016); CEP (2013); TÜV SÜD (2011b); Viesi et al. (2017) |
| Renewable and nuclear hydrogen | Naterer et al. (2008) |
| Renewable Hydrogen | Poullikkas (2007); Clark II (2008); Clark II and Rifkin (2006); Clark II et al. (2005); Clark (2007); FCH-JU (2014); Kameyama et al. (2011); Kramer et al. (2007); Ota et al. (2010); Public Citizen (2003); Rifkin (2002); State of California (2006); Tada et al. (2012); Weidong and Zhuoyong (2012) |
| Any low carbon hydrogen with low environmental impact | Çelik and Yıldız (2017) |
| Any low carbon hydrogen with an specific low carbon intensity | DECC (2015); Dincer (2012) |

Velazquez Abad, A. and P.E. Dodds, *Conceptualisation of Green Hydrogen Standards.* Renewable and Sustainable Energy Reviews (in preparation), 2018.

# Why is hydrogen of interest for policy makers?

- $H_2$FC can contribute to fulfil policy targets:
  - Economic growth drivers:
    - Industrial strategy & employment (Each £1 invested in $H_2$FC generates £1.5 for the UK Economy)
    - Not lagging behind, reconversion fossil fuel industry
  - Environmental drivers: Air quality (NRMM urban areas, Emission standards)
  - Climate change drivers: Increase use of renewables (via H2 storage) and GHG Emissions (clean pathways +CCS)
  - Energy security, reliability (flexibility pathways and feedtocks; P2G, G2P)
  - Energy affordability

# Economic Incentives around the world

<table>
<tr><th>Country</th><th>Residential CHP</th><th>Fuel Cell Vehicles</th><th>Refuelling</th></tr>
<tr><td>Japan</td><td>$93m<br>$700–1,700 / unit</td><td>$147m</td><td>$61m</td></tr>
<tr><td>Germany</td><td>$13,600 / unit</td><td>$4,000 / vehicle</td><td>$466m</td></tr>
<tr><td>China</td><td>–</td><td>$1,700 / kW<br>(up to $57,000 / vehicle)</td><td>$1.1m / unit</td></tr>
<tr><td>US</td><td>$1,000 / unit<br>(up to $3,000/kW for larger systems)</td><td>Up to $13,000 / vehicle</td><td>30% of cost (up to $30,000)<br>(California $100 M up to 2023)</td></tr>
<tr><td>South Korea</td><td>$5.3m</td><td colspan="2">$5.4m (up to $31,000 / vehicle)</td></tr>
<tr><td>UK</td><td>–</td><td colspan="2">$33m (60% of cost for refuelling)</td></tr>
</table>

**Summary of the support offered in various countries for hydrogen and fuel cells in 2017.**

Staffell, Iain, Daniel Scamman, Anthony V Abad, Paul Balcombe, Paul E Dodds, Paul Ekins, Nilay Shah, and Kate R Ward 2018. “The Role and Status of Hydrogen and Fuel Cells Across the Global Energy System”. Energy & Environmental Science. doi:10.17605/OSF.IO/RZM4G.

# What is going on in the $H_2$FC world?

| Country | CHP Units | Fuel Cell Vehicles | Refuelling stations | Forklift Trucks |
|---|---|---|---|---|
| Japan | 223,000 | 1,800 cars | 90 | 21 |
| Germany | 1,200 | 467 cars, 14 buses | 33 | 16 |
| China | 1 | 60 cars, 50 buses | 5 | N/A |
| US | 225 MW | 2,750 cars, 33 buses | 39 public<br>70 total | 11,600 |
| South Korea | 177 MW | 100 cars | 11 | N/A |
| UK | 10 | 42 cars, 18 buses | 14 | 2 |

**Summary of hydrogen and fuel cells uptake as of 2017**

Staffell, Iain, Daniel Scamman, Anthony V Abad, Paul Balcombe, Paul E Dodds, Paul Ekins, Nilay Shah, and Kate R Ward 2018. “The Role and Status of Hydrogen and Fuel Cells Across the Global Energy System”. Energy & Environmental Science. doi:10.17605/OSF.IO/RZM4G.

# What is going on in the $H_2$FC world?

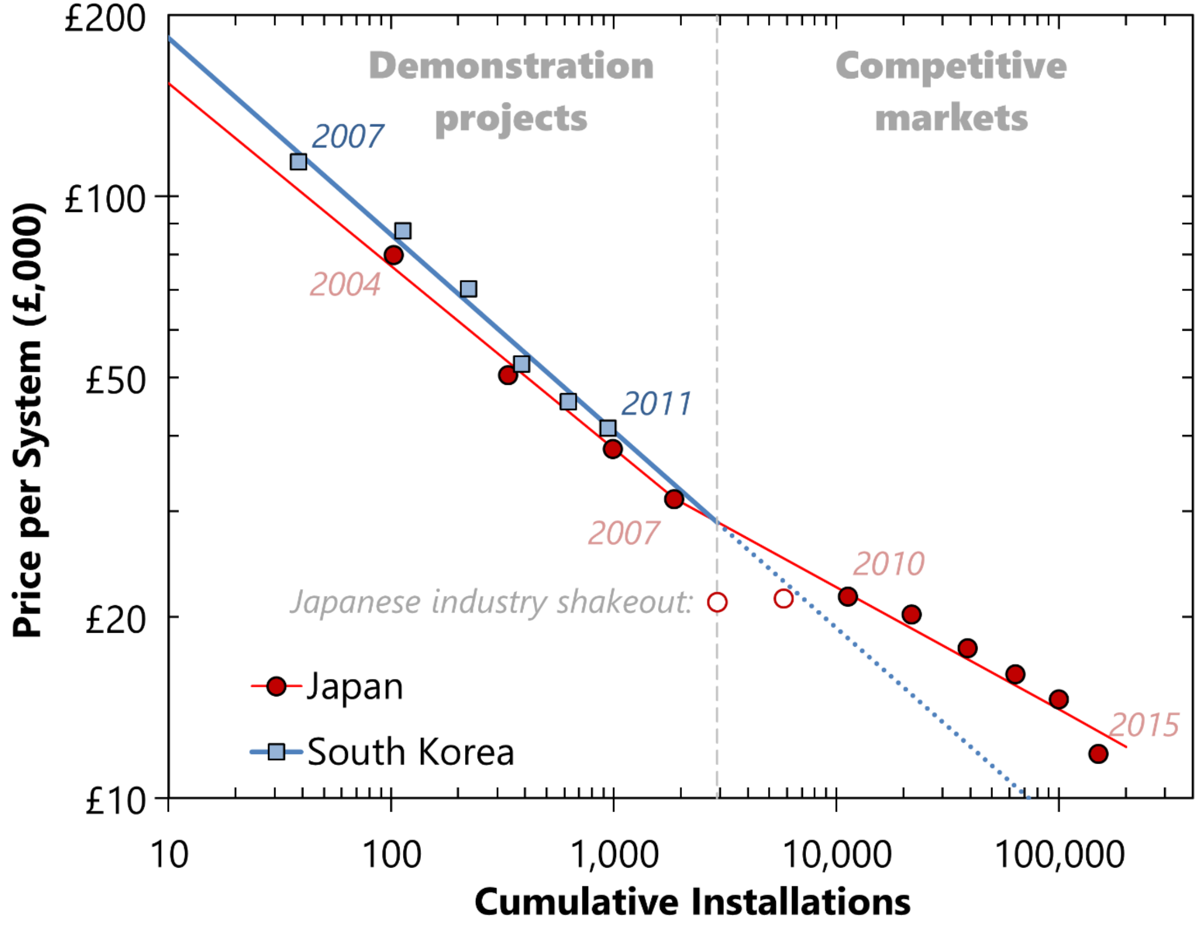
| Country | CHP | | Fuel cell cars | | | Refuelling stations | | |
|---|---|---|---|---|---|---|---|---|
| | 2020 | 2030 | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 |
| Japan | 1.4m | 5.3m | 40,000 | 200,000 | 800,000 | 160 | 320 | 900 |
| Germany | – | | 100% ZEV[a] by 2040 | | | 400 | | – |
| China | – | | 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 | – |

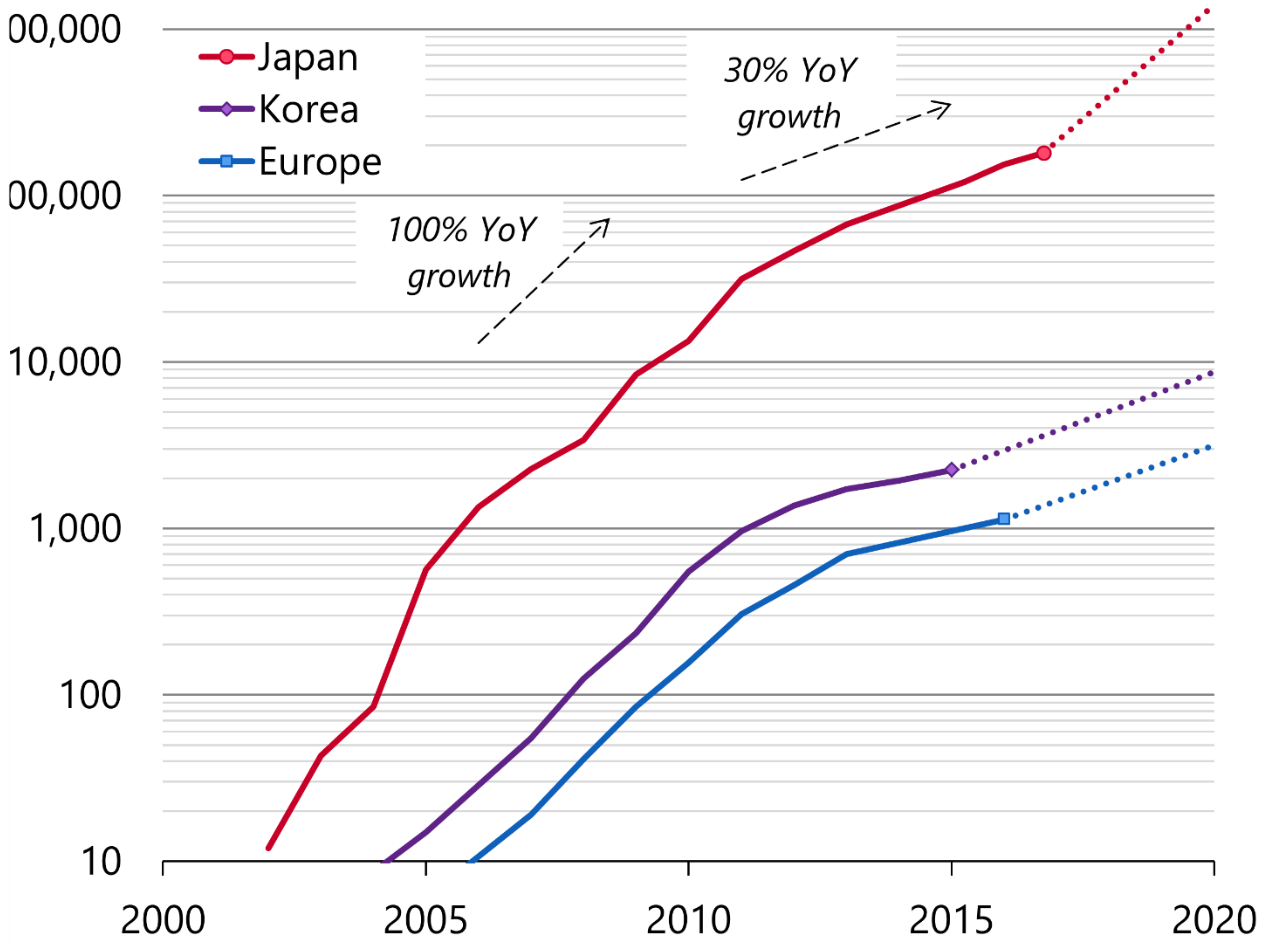
(a) Zero Emission Vehicle
(b) Shanghai only
(c) California only

**Summary of hydrogen and fuel cells uptake targets**

Staffell, Iain, Daniel Scamman, Anthony V Abad, Paul Balcombe, Paul E Dodds, Paul Ekins, Nilay Shah, and Kate R Ward 2018. "The Role and Status of Hydrogen and Fuel Cells Across the Global Energy System". Energy & Environmental Science. doi:10.17605/OSF.IO/RZM4G.

# Policy Driver: Economic Growth - Industrial Strategy
# Learning Curves and Economies of Scale: Heating

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# Policy Driver: Economic Growth - Industrial Strategy Learning Curves and Economies of Scale: Transport

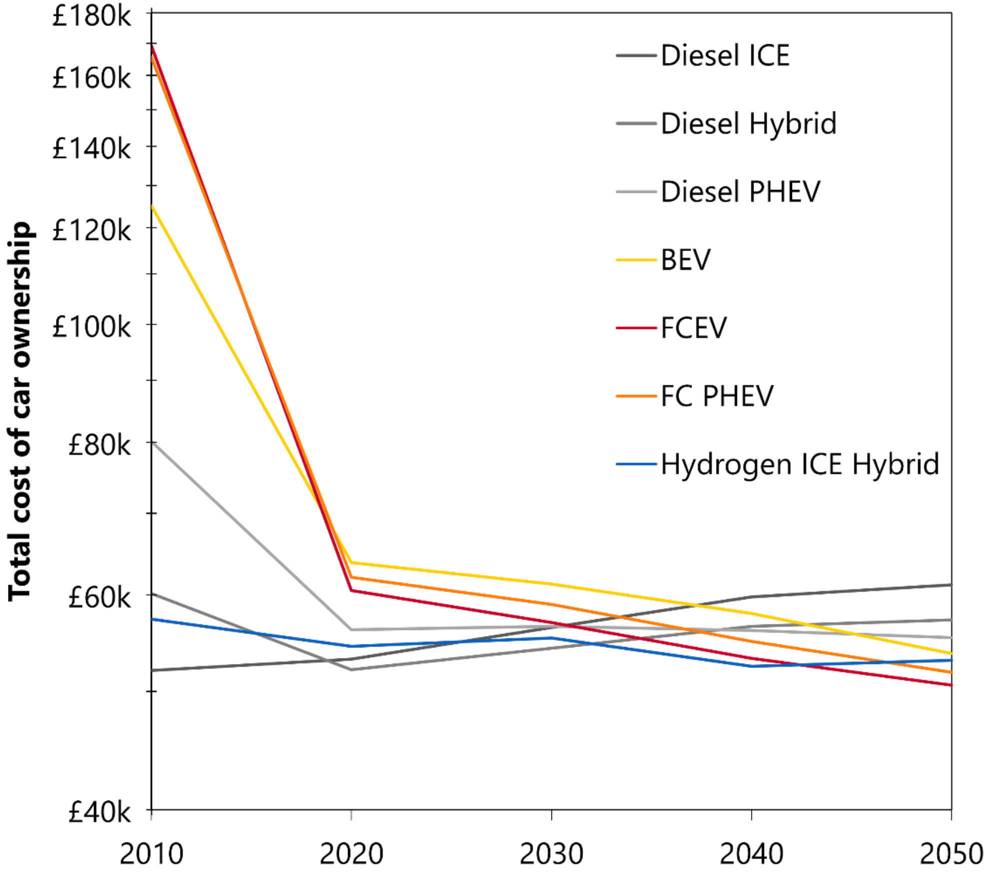



Table 8. Forecasted total costs of ownership of different vehicle types in 2030 and 2050 in GBP (1 GBP=1.15 EUR=1.23 USD). Adapted from 1. Körner, Tam, Bennett, and Gagné (2015) (BEV range = 150 km). 2.E4tech and Element Energy (2016). 3.Element Energy (2016).

| Source \ Type of vehicle | 1 (2030) | 1 (2050) | 2 (2030) | 3 (2030) | 4 [18] (2050) | 5 (2030) | 5 (2050) |
|---|---|---|---|---|---|---|---|
| ICE petrol | 22,845 | 23,902 | - | 21,593 | - | 27,365 | 27,876 |
| ICE Diesel | 23,414 | 24,471 | £28,800 | 21,188 | £61,000 | 27,873 | 27,114 |
| BEV | 24,227 | 25,447 | - | 21,907 | £54,000 | 30,161 | 27,368 |
| FCEV | 24,878 | 24,634 | £31,200 | 24,792 | £51,000 | 30,924 | 27,789 |

Velazquez Abad, A., *Techno-economic Comparison between Battery and Fuel Cell Electric Vehicles*, in *Southampton Business School*. 2017, University of Southampton: Southampton.

Staffell, Iain, Daniel Scamman, Anthony Velazquez Abad, Paul Balcombe, Paul E Dodds, Paul Ekins, Nilay Shah, and Kate R Ward 2018. "The Role and Status of Hydrogen and Fuel Cells Across the Global Energy System". Energy & Environmental Science. doi:10.17605/OSF.IO/RZM4G.

# Policy Driver: Environmental Driver – Reducing Emissions - GHG & AQ

Table 1. GHG emissions reductions to be achieved by different sectors in the EU by 2030 and 2050 to meet climate change targets. Adapted from: European Commission (2011b).

| GHG reductions compared to 1990 | 2030 | 2050 |
|---|---|---|
| Total | -40 to -44% | -79 to -82% |
| **Sectors** | | |
| Power ($CO_2$) | -54 to -68% | -93 to -99% |
| Industry ($CO_2$) | -34 to -40% | -83 to -87% |
| Transport (incl. CO2 aviation, excl. maritime) | +20 to -9% | -54 to -67% |
| Residential and services ($CO_2$) | -37 to -53% | -88 to-91% |
| Agriculture (non-$CO_2$) | -36 to -37% | -42 to -49% |
| Other non-$CO_2$ emissions | -72 to -73% | -70 to -78% |

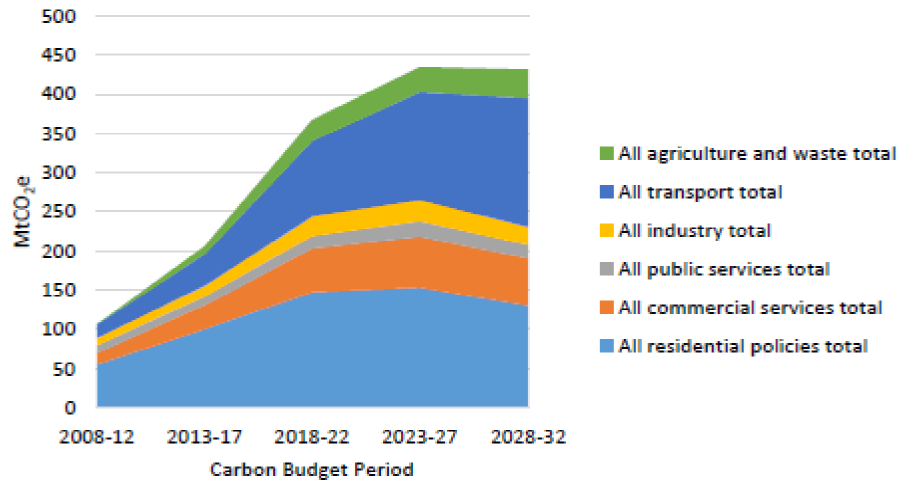
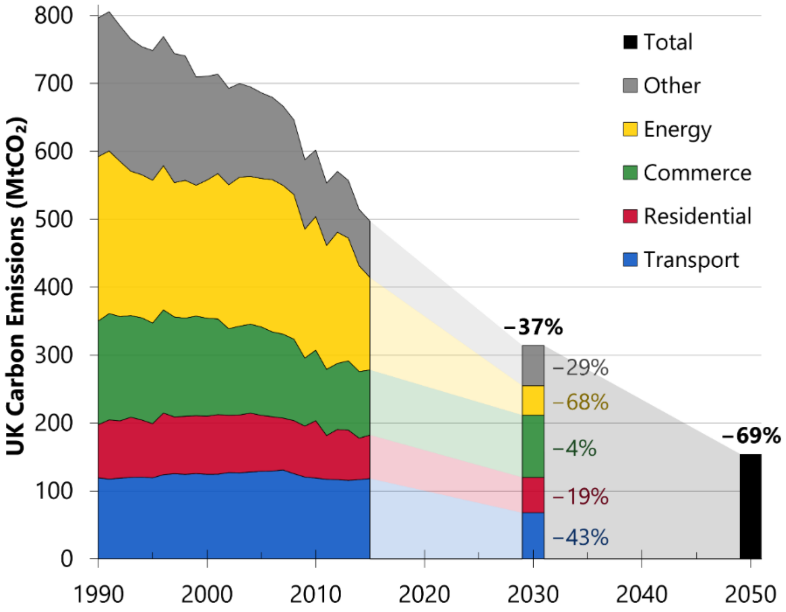



Figure 2. UK GHG Savings from policies by each sector according to the interim 'Carbon Budgets'. Adapted from DECC (2015).

1. there are several hydrogen pathways that can yield low well-to-wheel GHG emissions
2. Tailpipe emissions are negligible, which supports the Government's vision for almost every car and van to be an ultra-low emission vehicle by 2050 (and thus all new vehicles sold from 2040)

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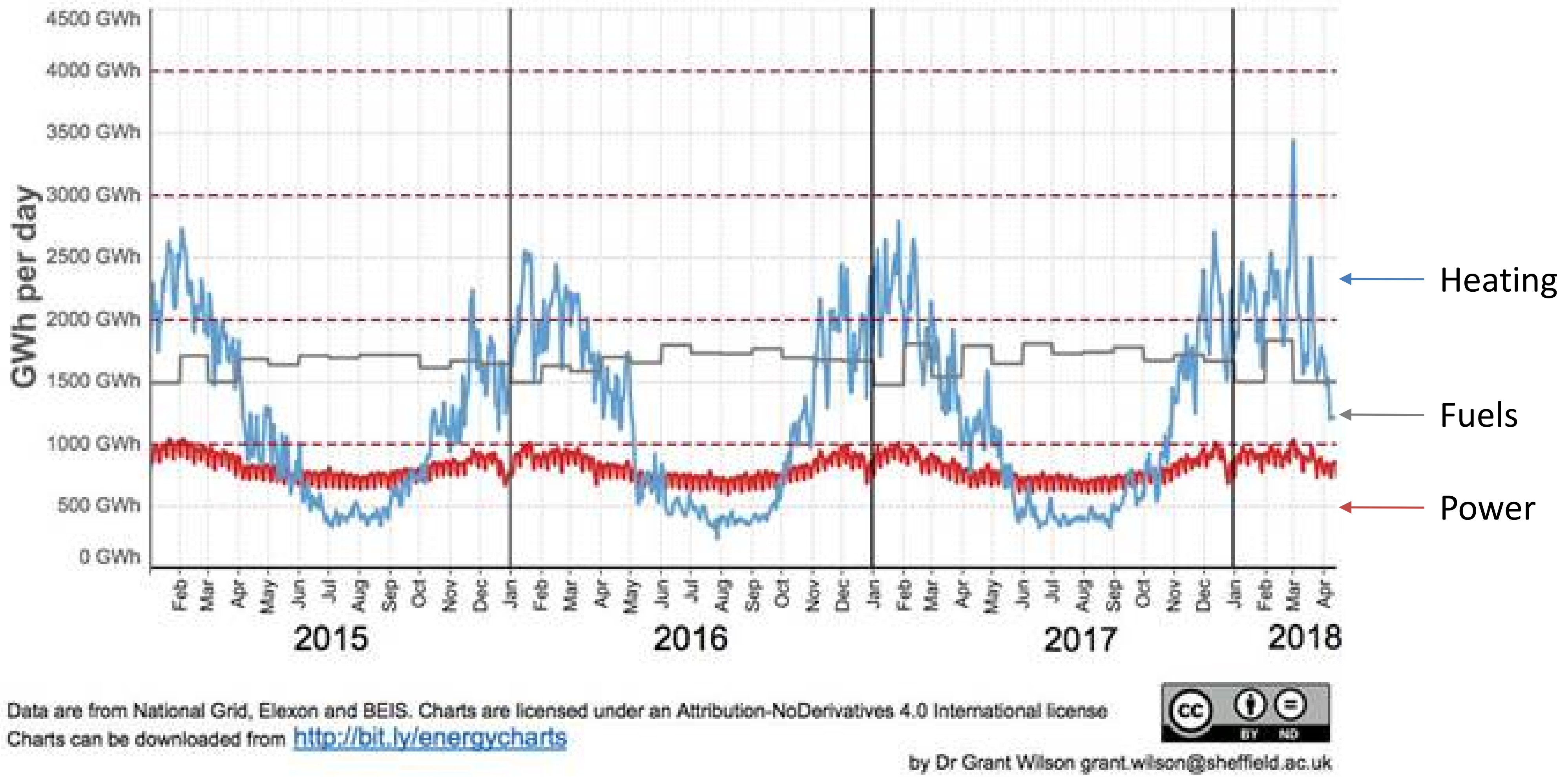
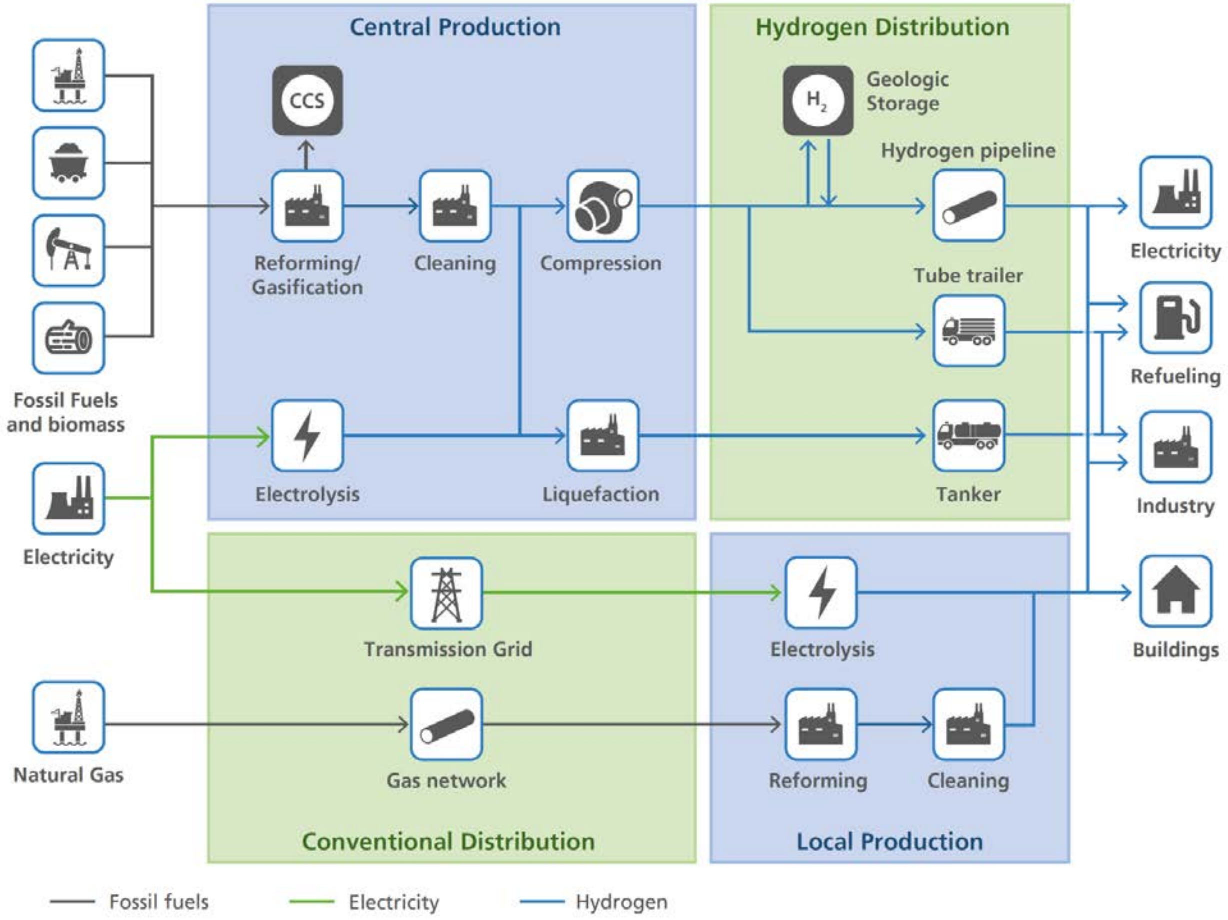
# Policy Driver: Increasing the use of renewables – H2 storage




Wilson, G. (2018). GB Daily Energy slidepack to April 2018. Sheffield, University of Sheffield.

# Policy Driver: Energy Security & Flexibility

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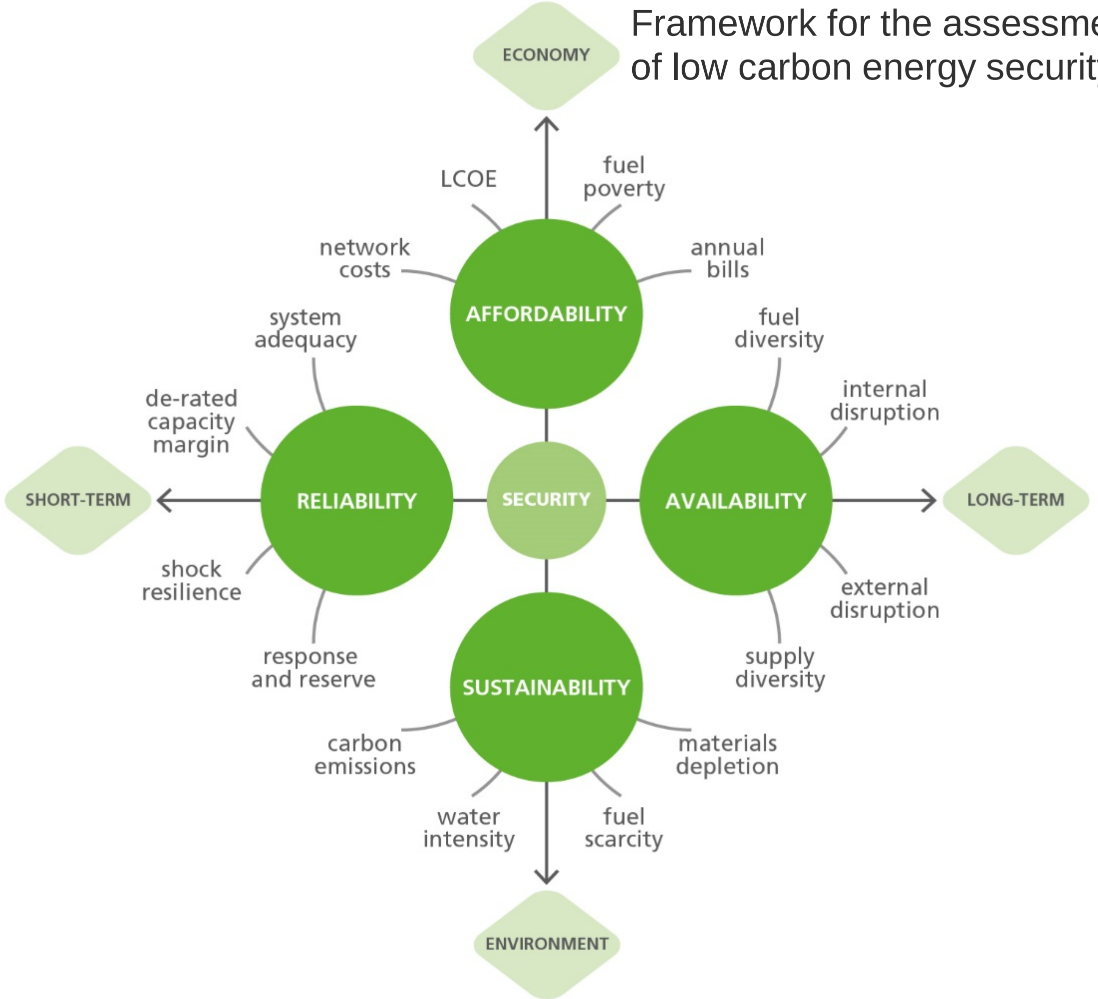
Framework for the assessment of low carbon energy security




Cox E. Assessing the future security of the UK electricity system in a low-carbon context. BIEE 14th Academic Conference. Oxford, UK; 2014.

# Policy Options: Energy Demand

| Buildings (Power / Heating) | Industry (Power / Heating) |
| --- | --- |
| UK Building Regulations | EU Emissions Trading System (ETS) |
| EU Energy Performance Buildings Directive | Climate Change Agreements |
| UK Private Rented Sector Regulations | Energy Savings Opportunity Scheme |
| UK Salix Loans | CRC Energy Efficiency Scheme |
| | Effort Sharing Decision, Effort Sharing Regulation |
| | Enhanced capital allowances (ECA) |
| | EU Industrial Emissions Directive (IED) |

Adapted from: Velazquez Abad, A., *Hydrogen Policy*, in *The role of hydrogen and fuel cells in future energy systems*, I. Staffell and P.E. Dodds, Editors. 2017, H2FC Supergen: London.

# Policy Options: Energy Demand

| Building Regulations | System: H, P | Objective: Energy efficiency / GHG emissions |
|---|---|---|

Sets standards for the construction and design of most new buildings and some renovations. Specify energy conservation requirements and must consider systems such as decentralised energy supply and district heating or cooling from renewables, heat pumps and cogeneration. Understanding hydrogen as a 'mains gas' could facilitate H2FC technologies to be installed in new buildings (e.g. hydrogen boilers, FC micro CHP).

Green hydrogen yes, brown/grey not! (SMR+CCS)

| Energy Performance Buildings Directive | System: H | Objective: Increase the share of renewables / Energy efficiency |
|---|---|---|

Mandates that all new public buildings built in the EU by 2019 must consume 0 kWh/m$^2$/year and other buildings by 2021. The Directive requires that energy used to operate buildings comes from renewables (mainly), therefore hydrogen must be renewable to be eligible. FC micro CHP running on biofuels could also meet the policy objective.

It is unclear if µCHP fuel cells powered by $H_2$ would be eligible (now tend to be powered by CNG)

| Salix Loans | System: H | Objective: Energy efficiency and reduction of GHG emissions, energy affordability, innovation |
|---|---|---|

A finance scheme funded by the UK Government that provides interest-free loans for energy efficiency projects undertaken by public sector organisations that yield a payback period under 5 years in England and 8 years for the rest of the UK. Lifetime carbon savings costs must be less than £100/t $CO_2$ in England (£200/t $CO_2$ in the rest of the UK). These cost savings can be recycled into new capital projects. Despite not including explicitly H2FC, such projects can meet the eligible criteria. Previous projects include boilers and NG CHP, which could also run on hydrogen.

Energy affordability may excludes  fuel cells

Velazquez Abad, A., *Hydrogen Policy*, in *The role of hydrogen and fuel cells in future energy systems*, I. Staffell and P.E. Dodds, Editors. 2017, H2FC Supergen: London.

# Policy Options: Energy Generation

| Residential / Industrial | Power Sector |
| --- | --- |
| Domestic / Industrial Renewable Heating Incentive (RHI) | Capacity Mechanisms (CM) * |
| Feed-in-Tariffs (FiT) | Contracts for Difference (CfD) * |
| Industrial Emissions Directive (IED) | Carbon Price Floor (CPF) |
| | Renewable Obligations |
| | EU Emissions Trading System (ETS) |
| Safety Regulations: % H2 in NG grid | Carbon Capture and Storage Directive (CCS) |

* This is about energy security, flexibility, reliability

Adapted from: Velazquez Abad, A., *Hydrogen Policy*, in *The role of hydrogen and fuel cells in future energy systems*, I. Staffell and P.E. Dodds, Editors. 2017, H2FC Supergen: London.

# Policy Options: Energy Generation

| Capacity Mechanisms (CM) | System: P | Objective: Energy Security |
|---|---|---|

Provides a payment to electricity generators to ensure that enough capacity is available in moments of stress on the power system. This is necessary given the rising proportions of renewables on the grid and intermittency of their output. Hydrogen storage can respond quickly and for long periods of time and it is adequate for transmission and distribution deferral, arbitrage, inter-seasonal and seasonal storage applications. CM should consider hydrogen as a special case and exempt it from the obligation to provide unlimited capacity, as reservoirs have a finite volume.

Reform of the electricity market

| Domestic Renewable Heating Incentive (RHI) | System: H | Objective: Increase the share of renewables / Reduction of GHG emissions |
|---|---|---|

A UK financial incentive to promote the generation and use of domestic renewable heat as a means to reduce GHG emissions. Eligible technologies include heat pumps, biomass boilers and solar thermal panels. A review should be put forward to assess the inclusion of FC micro CHP as this technology could deliver the same policy objectives as the accepted ones.

An update of the list of eligible technologies is needed!

Velazquez Abad, A., *Hydrogen Policy*, in *The role of hydrogen and fuel cells in future energy systems*, I. Staffell and P.E. Dodds, Editors. 2017, H2FC Supergen: London.

# Policy Options: Transport

| Transport policies (H2 and refuelling stations) | Transport capital and infrastructure financing policies for H2FCEV |
|---|---|
| Renewable Transport Fuel Obligations (RTFO) | Alternative Fuels Infrastructure Directive (AFID) |
| Regulations allowing H2 in conventional petrol stations | Enhanced capital allowances (ECA) |
| Vehicle emissions standards for heavy duty and light duty vehicles. | FCEV Fleet Support scheme |
| Congestion charges and low emission zones. | Local Sustainable Transport Fund |
| | Rail electrification |

Adapted from: Velazquez Abad, A., *Hydrogen Policy*, in *The role of hydrogen and fuel cells in future energy systems*, I. Staffell and P.E. Dodds, Editors. 2017, H2FC Supergen: London.

# Policy Options: Transport

| Renewable Transport Fuel Obligations (RTFO) | System: T | Objective: Reduction of GHG emissions |
|---|---|---|

Encourages the supply of renewable fuels. Producers must render renewable transport fuel certificates (RTFCs) to prove that they have met their Obligations (currently around 6% annual by volume). Producers of renewables can get income from their RTFCs. A new RTFO consultation process proposes to include hydrogen as a 'synthetic fuel from renewable electricity'. If successful, other renewable pathways will also be eligible (e.g. biomass gasification).

Renewable Fuel of Non-Biological Origin

Taxation of red diesel: implications for NRMM? (port/airport/rail/farm machinery & vehicles)
Phasing out fossil fuels by 2040: Implications for all transport modes: rail?

Types of policies:
Regulatory – RTFO x%, Green hydrogen Guarantees of Origin, fuel quality standards
Economic – Grants, low interest loans, subsidies (e.g. cost threshold)
Fiscal – Lower vehicle excise duty, lower fuel taxation
Innovation/Research – Calls Research Councils, EU Horizon 2020.

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# Conclusions

- The drivers for promoting H2FC in energy policy relate to reliability, efficiency and security of the energy system, reducing environmental impacts, and delivering economic growth. The potential of $H_2$FC technologies to contribute to all the dimensions of sustainable development (environmental, social and economic) justifies their systematic and long-term policy support.
- So far H2FC technologies cannot support policies targeting energy affordability. However, economies of scale could change this in the future.
- Policy makers must curate the wording of policies and they must enable policy neutrality to avoid the discrimination of H2FC compared with other technologies and energy carriers.

**H2FC has reached commercial maturity and policies must catch up with the markets to avoid hindering the uptake of these technologies!!!**

# Any Questions?

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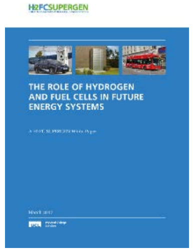


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