Introduction

Offering range and refuelling times similar to conventional vehicles, but with zero harmful tailpipe emissions, fuel cell electric vehicles (FCEVs) are seen by many as a crucial element of a low carbon transport future. An increasing number of automotive OEMs starting to offer FCEVs and continued investment in refuelling infrastructure in selected regions signal the growing momentum in the hydrogen transport sector.

This factsheet provides a high-level summary of relevant developments and future plans in key markets within this complex and evolving sector.

Vehicle availability

FCEV market introduction

Many global automotive OEMs are developing FCEVs, some have started to deploy vehicles in selected regions, and others have signalled their intent to bring hydrogen-fuelled cars to market within the next few years.

Company	Target launch markets	Commercialisation dates (based on public announcements)			
		Pre-2015	2015–2016	2017–2019	2020–2021
Hyundai	South Korea, California, Denmark, Sweden, Norway (Oslo), Italy (Bolzano), Germany, Austria, UK, Canada (Vancouver)				
Toyota	Japan, California (at 8 dealerships from autumn 2015), UK, Germany, Denmark				
Honda	Japan (from March 2016), followed by the US (California), and Europe within the following 12 months				
Daimler	Germany, California (others tbc)				
BMW	TBC				

Launch dates of selected OEM fuel cell electric vehicles based on public announcements (non-exhaustive)

Other car companies developing fuel cell vehicles include Nissan (working in a collaborative partnership with Daimler and Ford), General Motors (collaborating with Honda), and Volkswagen.

Target customers

First generation commercial FCEVs are being produced in small numbers and marketed in regions with some level of refuelling infrastructure (see below). A combination of relatively high vehicle prices and limited refuelling options as the networks develop will undoubtedly restrict the pool of customers for these innovative cars during the early phases of commercialisation. The earliest adopters of these vehicles are likely to fall into one of the following categories:

1) **Public sector fleets** – many cities suffer poor air quality and public sector organisations have an incentive to lead by example in taking action to reduce vehicle emissions in urban areas. The City of Copenhagen (Denmark) and Greater London Authority (UK) are examples of public authorities that have adopted FCEVs.
2) **Private sector fleets** – there is a market for FCEVs amongst some private sector fleets, particularly organisations with an interest in the successful development of the hydrogen transport sector and companies seeking to reduce the environmental impacts of their operations. For some fleets with well-defined operating patterns it is possible to provide fuelling from a single dedicated station, or small local network, without any loss of convenience. Examples include airport shuttle services, taxi companies and local delivery vehicles.
3) **Technology innovators** – a small number of FCEVs may be sold to private individuals with a strong interest in new technology and willingness to act as *technology innovators*.

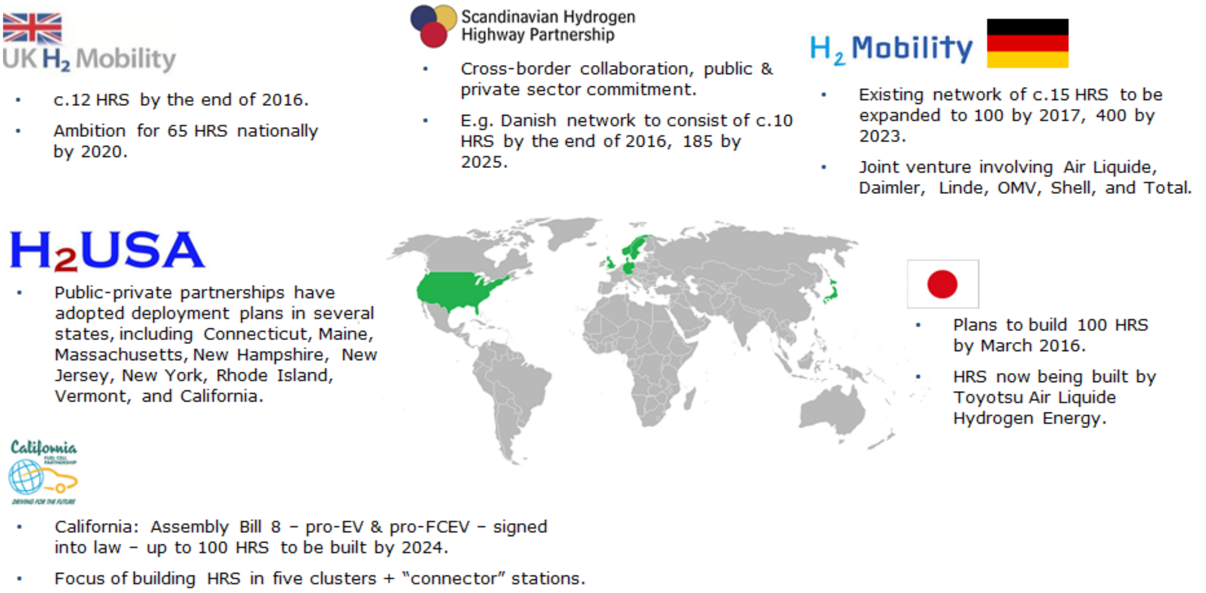
While the initial adopters of FCEVs will come from these groups, the range of customers procuring the vehicles will expand through time as fuelling networks expand, technology costs fall, and the range of vehicles offered increases. Hence as we move into the 2020s, the vehicles will increasingly become a mainstream choice for conventional customers.

Refuelling infrastructure

Overview

Most automotive OEMs are developing FCEVs based on storing gaseous hydrogen in on-board tanks at a pressure of 700 bar. An internationally agreed refuelling protocol is in place to ensure compatibility between hydrogen-fuelled vehicles and refuelling stations.

For FCEVs to fulfil their potential as a viable zero emission transport solution, networks of hydrogen refuelling stations (HRS) will be required. Such networks are being developed in some countries / regions around the world, as summarised below.



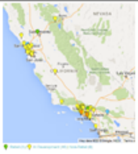
Summary of hydrogen refuelling station network development in selected countries (non-exhaustive)

Infrastructure deployment plans by country

In general, these national deployment projects have initially focussed on establishing a sparse network to allow testing of pre-series production vehicles by the earliest adopters. This has meant that in the leading national deployment centres, there are low tens of stations in operation as of the end of 2015. As new hydrogen-fuelled vehicles come to market, these initiatives plan to expand their networks to many tens or hundreds of stations to provide basic driving convenience to early adopters. These networks should be established before 2020, using a combination of public and private investments. From this point on demand for vehicles is expected to drive private sector investment in expanding networks.

Deployment plans for hydrogen refuelling stations can be compared with networks of charging stations for battery electric vehicles that allow rapid charging. For example, there are approximately 30 Tesla supercharger sites in the UK as of autumn 2015, many focused around London, but with a growing level of national coverage. A key difference between superchargers and hydrogen refuelling stations is that the former provide a range of around 170 miles after 30 minutes of charging, whereas FCEVs offer 300+ miles of driving after a 3–5 minute refuel.

Further details of the current status (late 2015) and near-term plans for hydrogen refuelling station deployment in some of the most advanced hydrogen transport markets are summarised in the following table.

Country / region	Status (late 2015)	Plans		Strategy
Japan	Tens of HRS open	100 HRS operational by March 2016		Cluster HRS in major population centres and provide strategic stations linking cities.
California	Around 20 HRS open	Plans for 50 HRS to be open by the end of 2016, >100 by 2021		Clusters of HRS in Berkeley, South San Francisco Bay Area, Santa Monica and West LA, Torrance and nearby coastal communities, Irvine and southern Orange County. Most HRS at existing forecourts.
Germany	Around 15 HRS open	50 HRS by 2016, 100 by 2017, 400 by 2023		National coverage from 2015/16, with most HRS on forecourts.
UK	Five publicly accessible stations operational	12 HRS by the end of 2016, vision for around 65 by 2020		Cluster stations in London / SE England initially, with strategic HRS near major routes.
Denmark	Seven HRS open	11 HRS by the end of 2016, plans for 100+ HRS by 2025		Provide basic national coverage from 2015, including links to Germany, Sweden, and Norway. Mainly standalone stations initially.

Source (maps)
www.h2stations.org/, www.cafcp.org/stationmap, http://cleanenergypartnership.de/en/customers/h2-filling-stations/ , H2Logic

Current status and future plans for HRS networks in selected geographies

Hydrogen refuelling station network economics

Investments in hydrogen fuelling stations can be characterised by an initial capital outlay to pay for building and installing the station, followed by on-going costs for maintenance / hydrogen production, and revenues (from sale of hydrogen). The capital costs of the stations are currently high, as the hardware needed is more complex than for conventional fuels, requiring gas compression and high pressure storage equipment. These high capital costs dictate the economics of any hydrogen station roll-out.

A positive return on investment relies on (i) the size of the margin on hydrogen sold (which must cover the initial capital outlay) and (ii) sufficient hydrogen sales (station throughput) over the lifetime of the asset. The margin on hydrogen is the difference between the cost of the gas to the station operator and price charged to the end user (excluding taxes). In order to provide an attractive case to potential adopters of FCEVs, hydrogen retail prices tend to be set relative to petrol / diesel to offer equivalent (or cheaper) fuel costs for FCEV drivers.

With this constraint, the investment case for small HRS is unattractive in the near term – i.e. when there are few FCEVs in the early stages of market development the demand for hydrogen is low and even small HRS are under-utilised, leading to insufficient revenues to cover the capital and operating costs. Hence in all areas developing hydrogen transport systems some form of public subsidy is required to justify the initial stations.

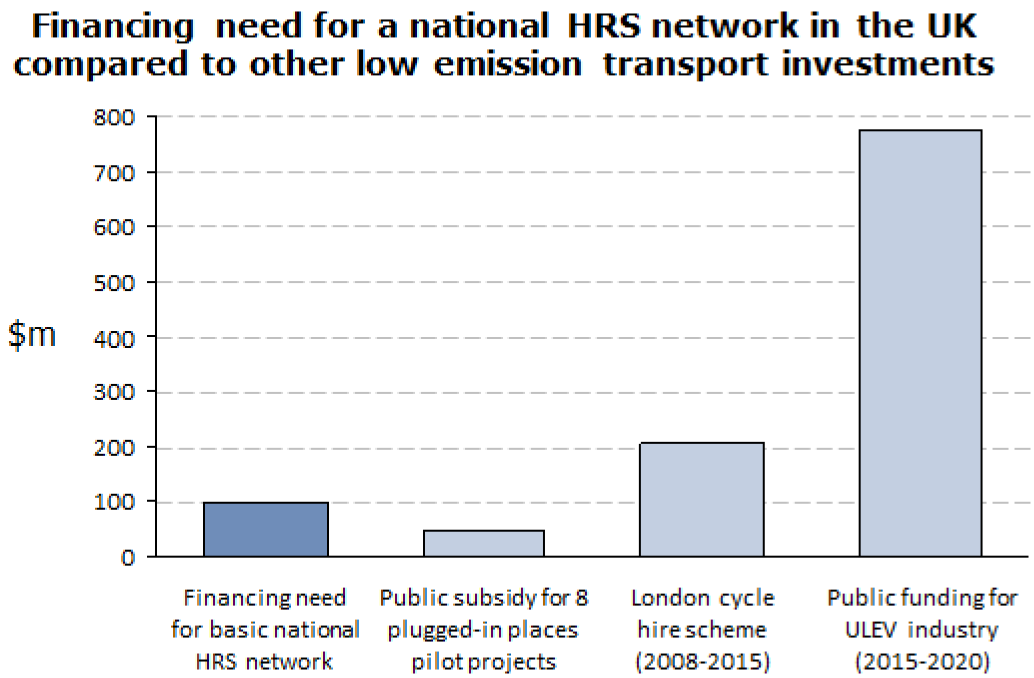
However, given sufficient demand for hydrogen, larger HRS with a reasonable throughput can offer a positive return on investment. Hundreds of cars in the fleet for each station is sufficient to achieve a positive return, even for fuel prices below those of conventional fuels. This compares to the thousands of petrol / diesel cars per conventional filling station.

To generalise, this means that a national hydrogen fuelling network should start to become bankable when there are ~10,000 cars on the road (assuming ~100 stations have been built by then).

A central challenge in delivering networks of hydrogen refuelling stations is how to transition from a non-bankable, subsidised early market phase when demand is too low to allow profitability to a commercial deployment phase where demand justifies investment in the network. Joint projects involving station providers and vehicle manufacturers, such as the H_2Mobility initiative in Germany, seek to address this issue by taking a coordinated approach to the deployment of fuel cell vehicles and hydrogen refuelling stations.

Costs of national HRS deployment plans

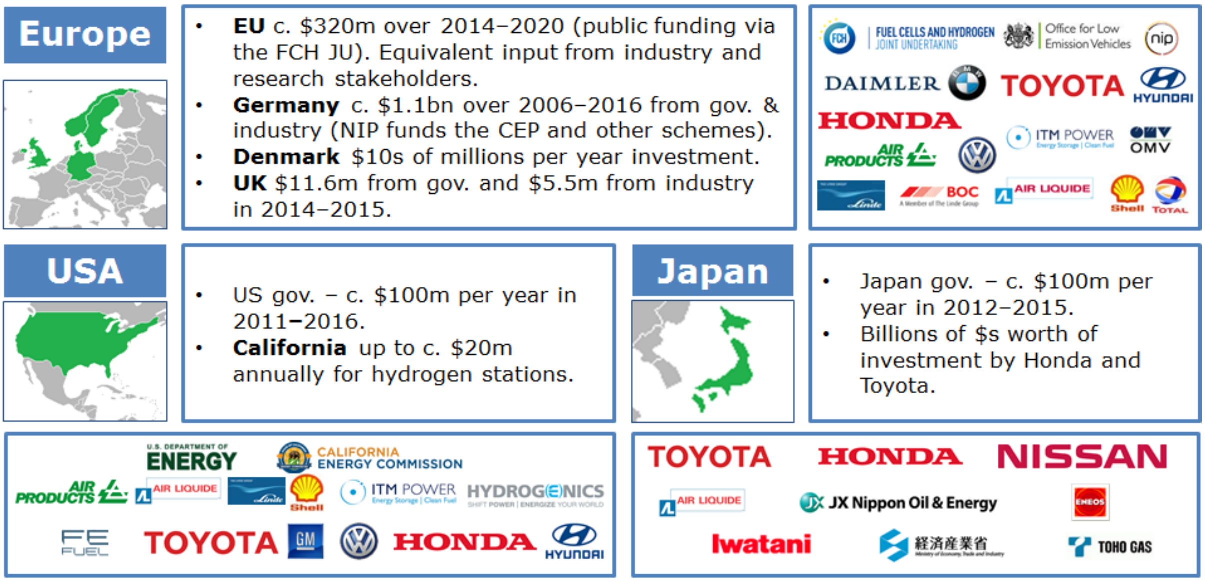
Installing a sufficient number of hydrogen refuelling stations to provide basic national coverage (tens to hundreds of stations depending on the country size) requires investments in the tens to hundreds of millions of $. For example, the financing need for a national HRS network in the UK has been estimated at around $650m to the point of break-even ($96m for the initial network of stations) [1]. The level of public subsidy is only a fraction of this; i.e. with the right risk sharing mechanisms in place much of this investment should be available from the private sector. Similarly, in Germany the plans to deliver 400 HRS by 2023 are estimated to require a total investment of approximately $375m [2]. While these figures may appear large, they are small compared to spending on incentives for technologies to decarbonise the wider energy system, which in both the UK and Germany are measured in $ billions per year [3]. The financing need for an initial network of 65 HRS in the UK relative to other transport schemes is shown in the following graph [4, 5, 6].



National HRS network financing need relative to other low emission transport investments

Stakeholders and committed investments

The hydrogen transport sector has seen considerable investments to date in research, development, and demonstration activities. This is illustrated in the diagram below, which summarises some of the public and private sector organisations working to develop hydrogen transport in selected markets, and indicates the scale of investment to date / planned in the near term [7, 8, 9].



Logos indicate examples of public and private sector organisations active in developing hydrogen transport market (non-exhaustive).
FCH JU: Fuel Cells and Hydrogen Joint Undertaking; NIP: National Innovation Programme; CEP: Clean Energy Partnership.

Overview of investment in hydrogen transport in selected markets

Worldwide fuel cell industry sales (including non-transport applications) exceeded $1bn for the first time in 2013, and the global hydrogen fuel cell transport market is forecast to grow to $18bn–$97bn per year over the next 10–20 years [10]. Vehicle OEMs have invested heavily in developing fuel cell technology to its current state of readiness for market launch and current indications are that investments in the $billions will continue over the coming years [11]. However, the economic impacts of hydrogen transport go well beyond automotive OEMs, as illustrated by a study carried out by the Fuel Cells and Hydrogen Joint Undertaking, in which hundreds of organisations with a stake in the sector were surveyed and which suggests that expenditure on hydrogen and fuel cell technologies in Europe alone is measured in the $billions/year [12].

Further information

If you have any queries or would like further information on the topics outlined above please contact PGMMarketDevelopment@angloamerican.com.

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Vehicle availability – fuel cell electric vehicle photographs

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Costs of national HRS deployment plans

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