UK H2 Mobility

Synopsis of Phase 1 Results

February 2013

Introduction

FUEL CELL ELECTRIC VEHICLES (FCEVs) provide the potential to decarbonise road transport, create new economic opportunities, diversify national energy supply, and reduce significantly the local environmental impacts of vehicles. The UK H_2Mobility project was established to evaluate the benefits of FCEVs to the UK and to develop a roadmap for the introduction of vehicles and hydrogen refuelling infrastructure.

In the first phase of the project, in 2012, a group of companies representing the whole value chain for FCEVs and the hydrogen fuel they use worked with government departments to develop this roadmap. The findings, summarised in this synopsis, show that FCEVs represent an attractive and sustainable long-term business proposition for all parties and that they can deliver important environmental and economic benefits to the UK. The up-front investment required is small in comparison to the benefits available. The project has quantified consumer demand for FCEVs and identified the early adopter groups. The results of the study provide the members of the project with the basis and the motivation to work towards an early market introduction for FCEVs.

Successful commercialisation will require the establishment of a hydrogen refuelling infrastructure to support vehicle sales. This necessitates a coordinated approach involving many parties from different sectors acting together. The UK H_2Mobility project membership comprises vehicle manufacturers, hydrogen producers, a fuel retailer, an energy utility, equipment manufacturers and government departments.

FCEVs will be introduced in suitable markets from 2015, with Germany, Scandinavia, Japan and California all preparing for the start of FCEV sales. The UK H_2Mobility members recognise the importance of prompt action to ensure the potential economic and carbon benefits of hydrogen transport are realised within the UK.

To build a fact base for the evaluation, the members of the project used their own data in combination with relevant information from previous studies and from published sources. Data on the performance, cost and availability of different classes of FCEV were aggregated and the costs of hydrogen production, distribution, storage, dispensing and retail calculated. In all cases, data were collated to cover the period 2015-2030.

Having assembled the most robust and detailed fact base possible, the project was able to develop a roadmap for the roll-out of hydrogen vehicles in the UK.

The UK H_2Mobility project:

- Evaluated consumer demand for FCEVs over time
- Determined the hydrogen refuelling infrastructure necessary to support the consumer demand and planned its development
- Identified a mix of production methods able to provide cost-competitive hydrogen to the consumer while delivering very significant CO_2 emissions reductions
- Quantified the benefits of establishing FCEVs in the UK market

The members of UK H_2Mobility that carried out the analysis described in this document were:

AIR LIQUIDE · BOC A Member of The Linde Group · DAIMLER · Department for Business Innovation & Skills · Department of Energy & Climate Change · Department for Transport · New Energy World JU fuel cells & hydrogen for sustainability · HYUNDAI · Intelligent Energy · ITM POWER Energy Storage | Clean Fuel · Johnson Matthey · MORRISONS · NISSAN · SSE · TOYOTA

McKinsey & Company and Element Energy Limited provided analytical support to the members of UK H_2Mobility during this phase of the study.
All values stated in this document are on the basis of 2010 real values and do not include inflation effects.

Consumer demand for FCEVs

Gaining an improved understanding of the potential buyers of FCEVs was a central focus of the project.

A series of consumer focus groups and interviews provided new insights into how consumers view hydrogen transport. The focus groups explored consumers' attitudes to FCEVs and related topics, including costs, performance (technical and environmental), safety and refuelling habits. The consumers were receptive to FCEVs, especially in terms of vehicle performance and refuelling time. However, in the early years after market introduction, FCEVs will be significantly more expensive to buy than conventional cars using combustion engines, and the refuelling network will be limited. These two factors were seen by the consumers surveyed as major barriers to buying an FCEV.

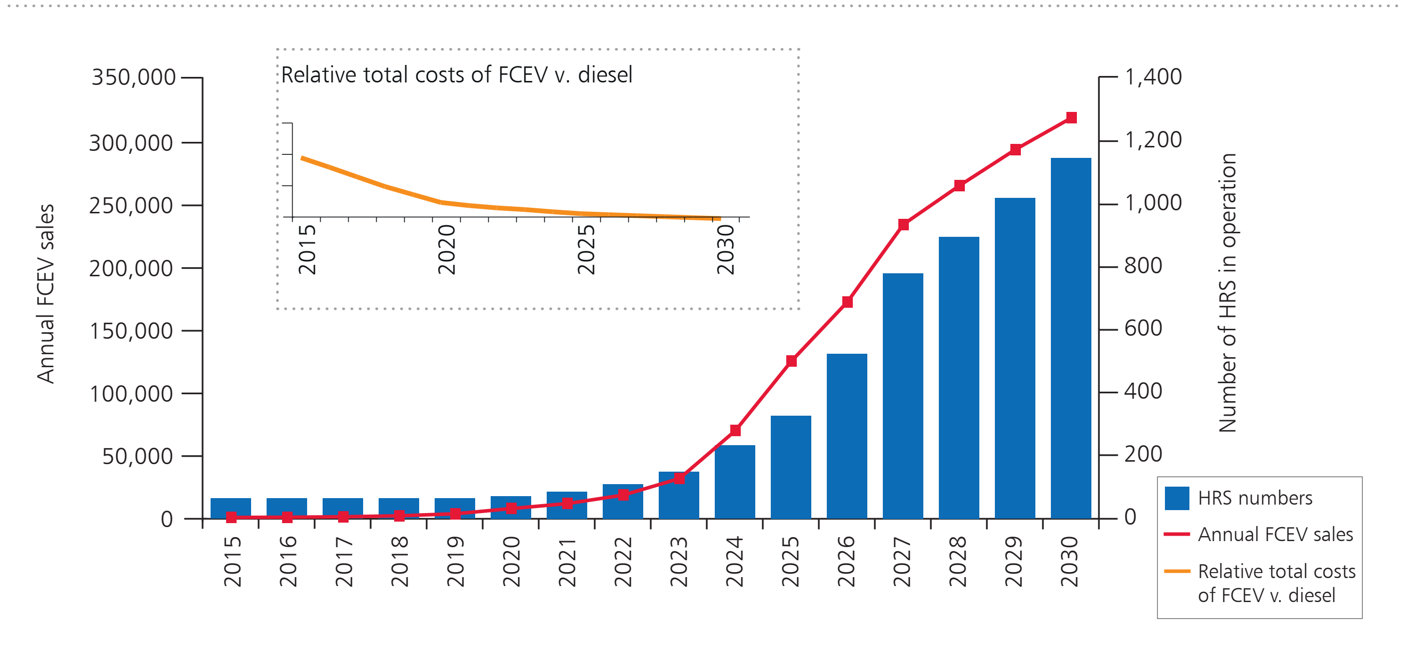
In addition, a quantitative survey was completed by 2,000 consumers who had recently bought, or were looking to buy, a new or nearly-new car. This was used to assess demand for the vehicles in different circumstances. Consumers were given information on the costs and performance, including environmental performance, of the vehicles. The information was based on a comparison between an FCEV and an equivalent vehicle with a diesel engine using the total cost of ownership over the first four years of the vehicle's life. The costs considered included purchase price (including VAT) less the residual value, financing, fuel, maintenance and servicing, insurance and road tax. (Although the project assumed a continuation of preferential road tax rates for zero CO_2 cars, no other financial incentives were included.)

The project was able to segment the market into groups of consumers with similar attitudes to the particular characteristics that they value in a car, to new technology, to the environment and to costs. For each group, the dependency between total costs, availability of hydrogen refuelling stations (HRS) and the decision to buy an FCEV was quantified. Some 10% of new car buyers showed themselves to be potential early adopters of FCEVs, being receptive to new technology and environmentally motivated.

The survey provided new understanding on how far different types of consumer would be prepared to drive to an HRS. It also assessed the difference between the price a consumer would be prepared to pay for an FCEV and for an equivalent diesel vehicle. This price difference was found to depend largely on the availability of HRS, but varied greatly between different consumer groups.

From the quantification of the dependencies between costs, vehicle performance and HRS network development, the project developed a model to predict the rate of vehicle uptake in different circumstances. This model indicates that, once HRS are available, the initial uptake will be limited by the cost of buying the vehicles. Nevertheless, the analysis identified sufficient early adopters to generate sales of approximately 10,000 p.a. by 2020. As the vehicle costs become more competitive and the refuelling infrastructure develops, consumer uptake is calculated to increase rapidly. In the UK H_2Mobility roadmap, by 2030 there will be 1.6m FCEVs in the UK with annual sales of more than 300,000 (see Figure 1).

Figure 1: UK consumer demand for FCEVs increases as the cost premium diminishes and the network of HRS expands.



The hydrogen refuelling infrastructure

It is important for the HRS network roll-out to strike a balance between maximum customer convenience (and therefore FCEV uptake) and investment required.

Consumers require both local availability and national coverage, and the quantitative survey showed them to be significantly more receptive to FCEVs if they have access to more than one HRS locally. Detailed spatial modelling identified those locations which deliver the greatest customer benefit. It showed that a roll-out targeting particular areas and the national trunk routes is the most efficient early strategy.

The analysis and network modelling undertaken within the project indicated that 65 stations across the UK could provide sufficient initial coverage to start the market, covering major population centres (with more than one HRS) and connecting roads (see Figure 2). Thereafter, the network develops with the demand for hydrogen. The roadmap shows full national coverage with 1,150 stations by 2030, providing close-to-home refuelling for the whole of the UK (see Figure 3).

In the market conditions assumed in the UK H_2Mobility roadmap, the HRS network as a whole will not be profitable initially but will be able to cover its operating costs by the early 2020s and to reach break-even in the late 2020s. In the roadmap, the total financing need up to the break-even point is £418m, of which £62m is required before 2020.

The low utilisation of the HRS network before 2020 will hurt profitability and analysis of the economics of individual stations shows that the early stations will not be able to deliver the same returns as those built later. There exists therefore a challenge in securing the initial investment and some support for seeding the market may be required. The next phase of the UK H_2Mobility project will look to develop potential business cases for the initial network of stations, including identifying how utilisation rates might be improved and how first mover commercial advantage could be secured.

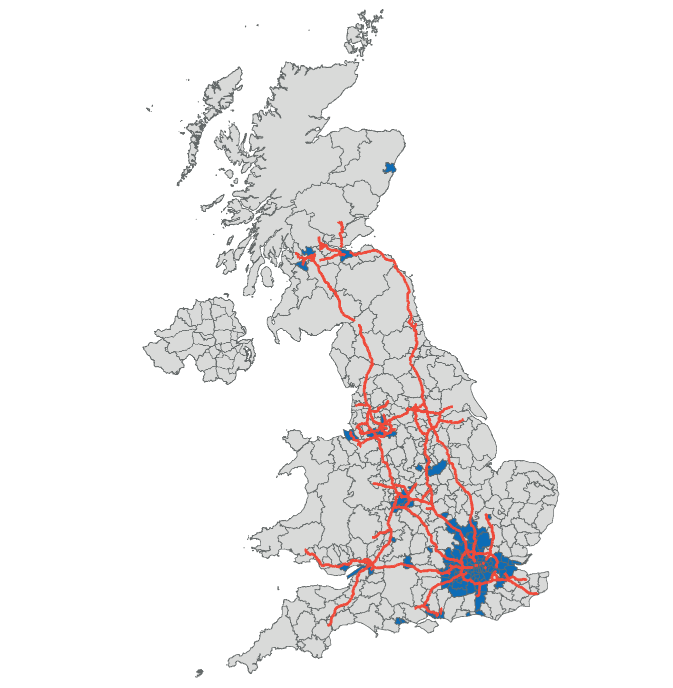
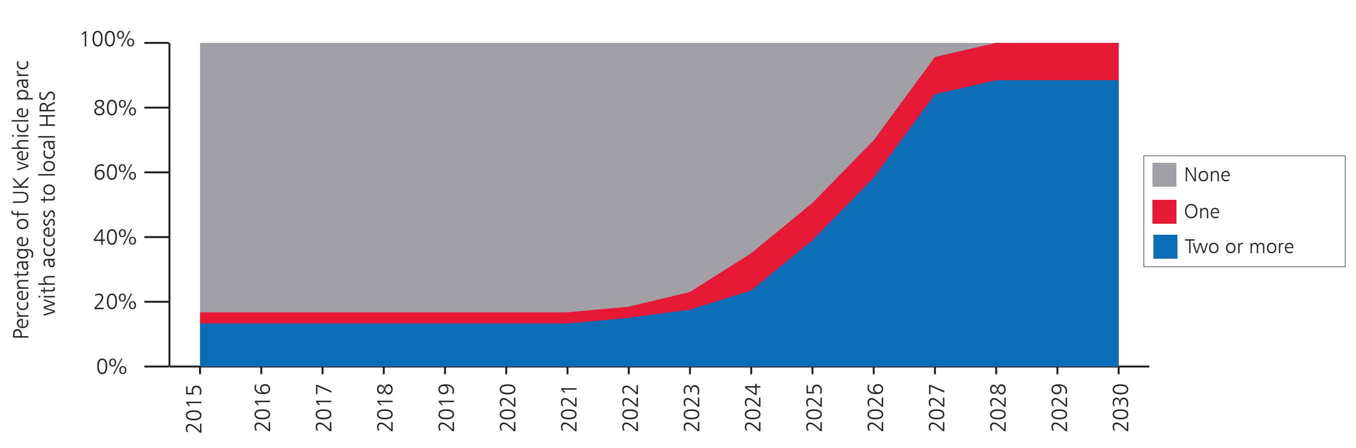


Figure 2: Initial HRS network coverage of trunk routes and major population centres in 2015.

Figure 3: The development of local HRS network coverage in terms of the proportion of the UK vehicle parc with access to zero, one and two or more HRS in their local district.



Hydrogen production and distribution

The consumer research carried out in the project and the UK's decarbonisation objectives each defined a need for low and reducing CO_2 emissions for each km driven by an FCEV.

While FCEVs themselves emit no CO_2, some processes for hydrogen production do and so the measure must account for any CO_2 emitted during fuel production. Therefore, the project members designed a mix of hydrogen production technologies for the roadmap that is at least competitive with other advanced low-emission vehicle technologies in the early years and is on a plausible path to full decarbonisation by 2050.

Using the project fact base, the analysis shows that a mix of hydrogen production methods can deliver hydrogen to the driver at a cost competitive with diesel, yet with 60% lower CO_2 emissions in 2020 and 75% lower in 2030 (see Figure 4).

The hydrogen production mix in the roadmap for 2030 is 51% water electrolysis, 47% steam methane reforming (SMR) and 2% existing capacities. (The existing capacities are a mix of SMR and readily available by-product hydrogen from other processes.) The water electrolysis, using renewable electricity, includes both on-site production at the HRS and centralised production with distribution to the HRS. In 2030, the roadmap shows that the national demand for hydrogen for FCEVs will be 254,000 tonnes p.a. (see Figure 5).

Water electrolysis capacity offers significant benefits to the electricity sector in assisting the integration of renewable generating capacity and in providing grid-balancing services. These benefits will increase as the proportion of renewable energy in the generating mix increases. The project quantified these benefits and determined that this would have the effect of reducing the cost of hydrogen produced by electrolysis by 20%.

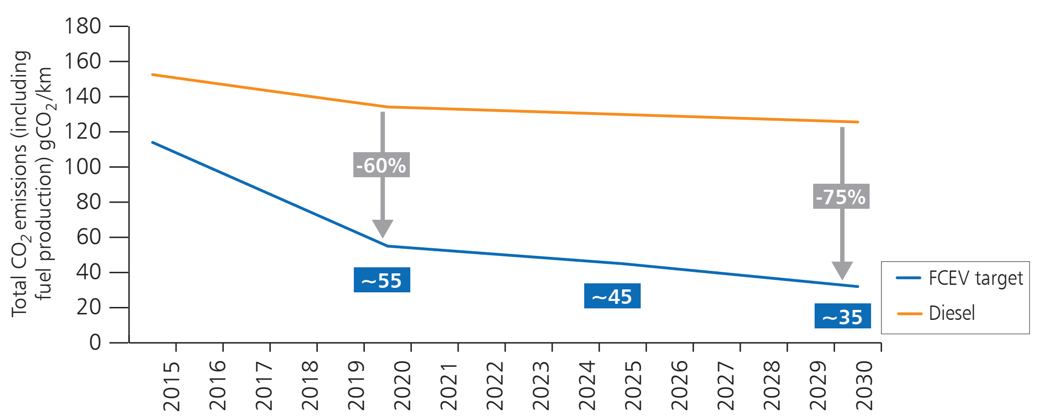


Figure 4: The path for the CO_2 intensity of hydrogen used in FCEVs selected by the project members for the roadmap.

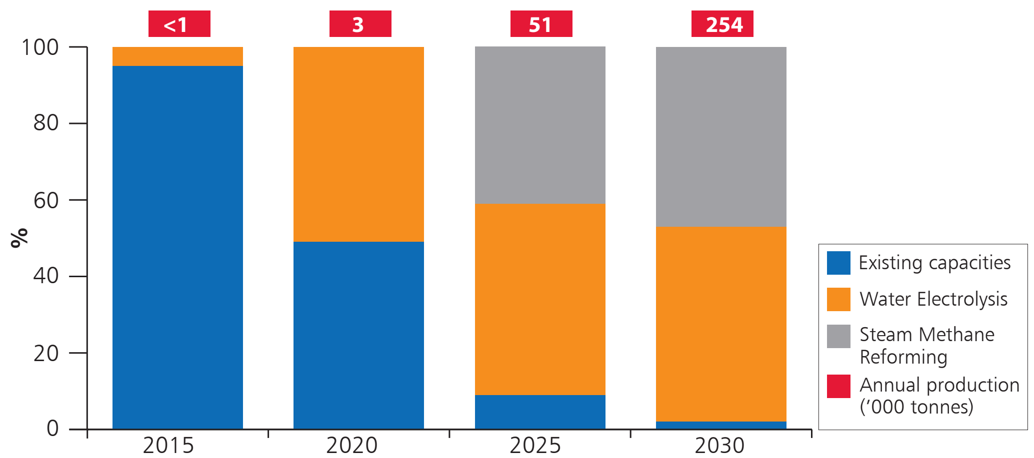
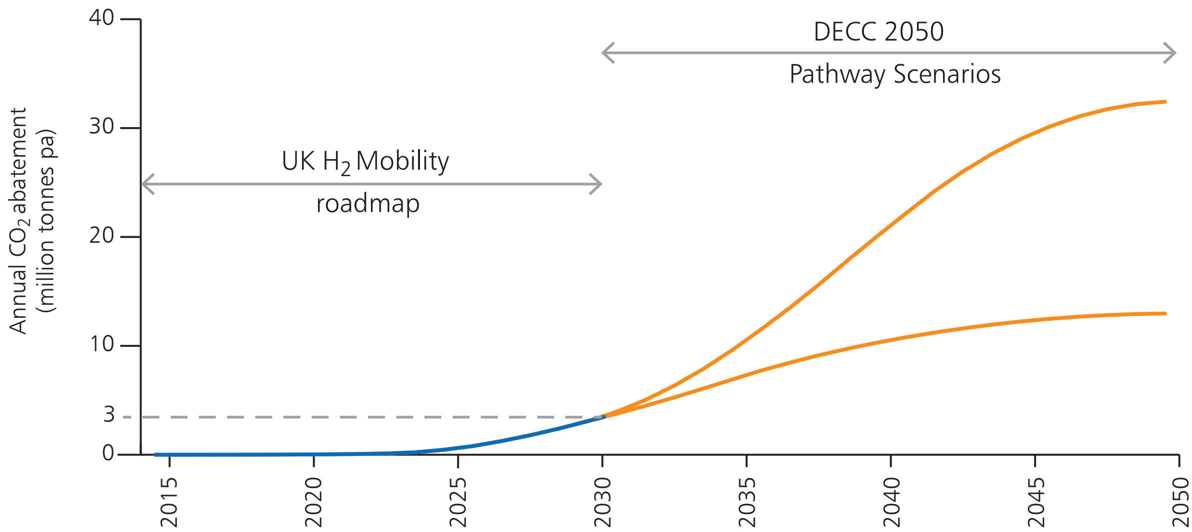


Figure 5: The development of hydrogen production capacities over time in the roadmap.

The benefits of FCEVs

The UK H_2Mobility roadmap shows that the total CO_2 emissions for an FCEV can be 75% less than the equivalent diesel vehicle in 2030, on a path to zero carbon by 2050. The total annual CO_2 abatement implied is 3m tonnes in 2030, using the vehicle uptake in the roadmap. The DECC 2050 Pathway Analysis has scenarios for FCEVs as a proportion of the total UK fleet of between 20% (7m vehicles) or 50% (17m vehicles). The UK H_2Mobility roadmap puts the UK on the right path to meet these scenarios (see Figure 6).

Figure 6: Annual CO_2 abatement from the UK H_2Mobility roadmap (to 2030) and DECC Pathway Scenarios (2030-2050).



Using DEFRA's Air Quality Damage Cost Guidance, it is possible to quantify the benefit of replacing diesel vehicles, which emit oxides of nitrogen (NOx) and particulate matter (PM), with FCEVs emitting only water vapour. The cost saving that accrues from reduced damage to human health and the environment is £100m – £200m annually by 2050 (depending on the rate of growth of FCEVs in the total fleet after 2030).

The hydrogen production mix in the UK H_2Mobility roadmap shows a further benefit of FCEVs: a greater proportion of UK's road fuel (measured both by financial value and energy content) would be made in the UK. This is because more of the process inputs are locally produced and because the economics of hydrogen production and distribution favour local production. As well as obvious benefits for energy security, switching from imported fossil fuels to hydrogen made in the UK would deliver a £1.3bn annual benefit to the UK economy by 2030.

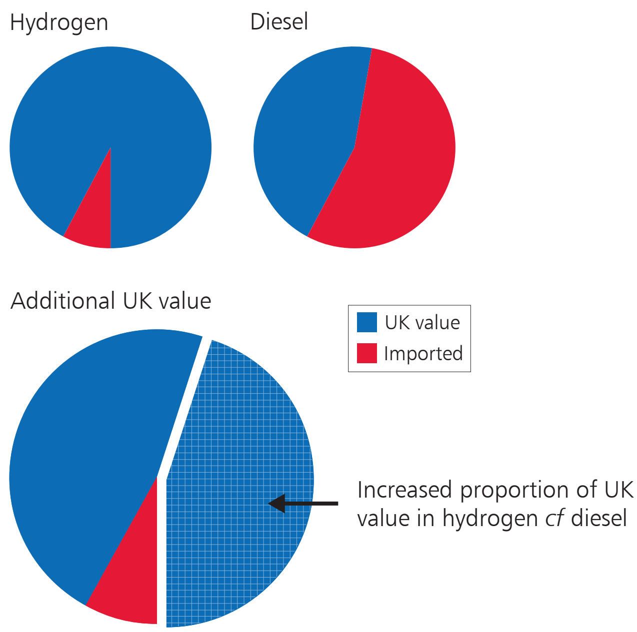


Figure 7: Value of increased domestic energy production and reduced imports in 2030.

Key achievements of Phase 1 of UK H_2Mobility

During 2012, the UK H_2Mobility project achieved the following:

- Assembled a comprehensive fact base, specific to the UK, covering FCEVs, HRS and the means of hydrogen production and distribution. This fact base is available to the members as a fundament to further phases of the project and for their own planning.
- Gained novel insights into consumer perceptions of FCEVs and the factors influencing purchasing decisions. Importantly, it quantified the impact of non-financial decisions on the amount that consumers are willing to pay for an FCEV in different circumstances and identified those customer groups most likely to be the first buyers of FCEVs. These results define the conditions needed for a successful market introduction.
- Investigated a broad range of hydrogen production methods and quantified, for the first time, the benefits that hydrogen production by water electrolysis can have on the UK electricity grid, particularly with respect to the integration of generating capacity for renewable electricity.
- Analysed UK vehicle ownership and traffic density and applied the findings of the consumer research to derive a plan that describes the roll-out of a national network of HRS. Significantly, an initial network of 65 stations would be enough to attract buyers in targeted areas and allow them to drive nationally.
- Quantified the cost of building the HRS network. In the roadmap, the total financing need up to the break-even point is £418m, of which £62m is required before 2020.
- Combined all these elements into a credible roadmap which shows how, by 2030:
  - FCEVs will be at least cost-competitive with conventional vehicles
  - A network of 1,150 HRS covering the whole country can be built
  - 1.6m FCEVs could be on UK roads
  - The HRS network is past its break-even point
  - Hydrogen production and retailing can be an attractive and profitable business leading to the natural growth of the HRS network as the car fleet grows
  - CO_2 emissions (including fuel production) can be 75% lower for FCEVs than for equivalent diesel vehicles, and on a trajectory to zero CO_2 emissions by 2050
  - FCEVs will be on course to reach a 20-50% market share, in line with the DECC 2050 Pathway Analysis.
- Identified the challenges that must be overcome in order to deliver the roadmap.

Objectives for Phase 2 of UK H_2Mobility

Building on the roadmap developed in Phase 1, the second phase of UK H_2Mobility in 2013 will:

- Develop a detailed business case and an overarching framework to enable all entities involved to commit to specific actions
- Identify instruments and mechanisms necessary to overcome the barriers to achieving the roadmap. As identified in Phase 1, the key points to address are:
  - The commercial model for the construction of the initial network of HRS
  - Options for improving the early consumer proposition, and
  - The means to establish a clear pathway, with controls, to the production of low carbon hydrogen with the right purity for FCEVs

For further information on UK H_2Mobility, please contact any of the participants listed in the introduction.

For general enquiries, please email olev.enquiries@olev.gsi.gov.uk