Hydrogen Mobility Europe

Business Case Assessment and Customer Value Proposition Analysis (WP5)

Deliverable 5.16	Strategic recommendations for supporting the commercialisation of fuel cell electric vehicles in Europe (Final)
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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Executive Summary

The demand for hydrogen mobility is now evident, but a significant increase in scale of local activities is needed to accelerate cost reductions and supply chain development

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Summary (1/2)

- **The H2ME project has demonstrated the viability and practicality of FCEVs of different sizes in meeting the needs of a range of existing vehicle users; close to two thousand hydrogen vehicles are in operation in Europe.**
  - Several countries now have hundreds of fuel cell cars and vans (FCEVs) in operation. The largest concentrations are found in taxi and ride-sharing fleets in city centres (e.g. 100 taxis in Paris), as well as an increasing number of business users and company cars, especially in Germany.
  - These applications depend on the ability to refuel rapidly and complete high daily mileages when required; the growth in demand for FCEVs in these applications clearly demonstrates that they can meet these needs and offer an attractive customer proposition.
- **Localised networks of public refuelling stations have been developed in numerous European cities**
  - Where dense concentrations of high-mileage FCEVs exist, there is an attractive business case for the development and operation of local networks of hydrogen refuelling stations (HRS), and cities such as Paris, London, and Berlin now have city-wide HRS networks, ensuring that FCEV fleets can operate flexibly within these locations.
- **Nationwide networks are in place in Germany and Denmark, but utilisation is currently low relative to capacity**
  - Initial national refuelling networks have been developed to support the adoption of passenger cars, but current levels of demand are not sufficient to support a long-term business case. Future development of these networks will link new HRS deployment locations to emerging demand, to make HRS operation more investible.
- **The further commercialization of hydrogen mobility relies on scaling up demand, including demand from heavy vehicles**
  - The business case for hydrogen production from renewables and operating refuelling stations is currently challenging due to the scale of demand relative to the costs of installing and operating infrastructure. With a higher magnitude of demand, both stations and hydrogen production can become more cost-effective, and the development of the European supply chain will accelerate, bringing improved station reliability and economic opportunities.
  - The focus of many hydrogen mobility initiatives has shifted towards heavy duty applications, where demand per vehicle is much higher and the benefits of hydrogen over other alternatives are more critical. Refuelling infrastructure for passenger cars and vans can be developed alongside this: a) by ensuring that stations primarily used by heavy vehicles are also capable of refuelling light vehicles and b) developing local clusters for applications such as taxis.

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To achieve scale, what is now needed is a clear policy push in favour of hydrogen for mobility, with financial support for hydrogen as a fuel as well as for vehicles

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Summary (2/2)

- **To enable scale-up of the fuel cell vehicle fleet, national subsidies and incentives are needed for all vehicle types**
  - Although demand is steadily growing, production volumes of fuel cell vehicles are still relatively low, especially for heavy duty vehicles, and vehicle costs will be significantly higher than those of fossil fuel vehicles while the supply chain matures and production volumes continue to ramp up. Purchase incentives that bring the on-the-road costs of hydrogen vehicles in line with fossil fuel options are needed to unlock demand from vehicle operators and bring market confidence to vehicle suppliers.
  - Incentives to be applied at the national level could include purchase grants and various tax exemptions; policies similar to those applied to Battery Electric Vehicles are likely to be appropriate, but subsidy levels should account for the current lower maturity of the FCEV market compared to BEVs.
- **Fuel credits for renewable hydrogen are needed to stimulate demand and production**
  - In the initial phases of scale up, the cost of producing and retailing renewable hydrogen is likely to exceed its value to vehicle operators. Fuel credits for renewable hydrogen would help to strengthen the business case for renewable hydrogen production and retail in the face of uncertainty around future demand.
  - The wording of the second Renewable Energy Directive (RED II) gives member states the freedom to support hydrogen produced from renewable sources (biomass and renewable electricity) with higher credit values, either through multiple counting of credits or by including hydrogen as an advanced biofuel.
  - Fuel credits with a value of around €4/kg of renewable hydrogen would enable retailers to make it available at an attractive price.
- **National governments can remove barriers to hydrogen mobility by ensuring that hydrogen options receive equal treatment to other zero emission alternatives within transport strategies and policies**
  - Specific measures to be adapted will vary for each country, but may include specifying hydrogen as an option for innovation & demonstration projects, updating regulations and zero-emission vehicle to include specifications for hydrogen vehicles, and ensuring that guidance on HRS installation is available to planning authorities.

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Introduction

The commercialisation of hydrogen mobility is a vital part of the transition to a net zero Europe by 2050

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Context of this report

- Numerous governments across Europe have recently committed to limiting the increases in global temperatures by achieving carbon neutrality by 2050. As part of this, rapid reductions in carbon emissions from transport are needed.
- Part of the strategy to achieve this is a switch to **vehicles with zero harmful emissions at the tailpipe**, and very low emissions on a "well-to-wheel" basis – such as battery electric or **hydrogen fuel cell electric vehicles (FCEVs)**.
- FCEVs run solely on **hydrogen, which can be produced through various low carbon production methods**, including electrolysis with renewable electricity and (in the future) reformation of methane with carbon capture and storage.
- **Thousands of hydrogen cars are now in use worldwide**, and in Europe numerous fleet users such as taxi and ride-sharing companies are putting them to use in high mileage applications – evidencing the readiness and suitability of the technology for commercial applications. In parallel, the hydrogen refueling network in Europe is growing steadily, with over 130 refueling stations installed to date.
- However, hydrogen mobility is not yet fully commercialized, and there are still several barriers to wider adoption of hydrogen transport technologies, with the **limited refuelling infrastructure** and **high costs** continuing to be the most significant.

Hype hydrogen taxis in Paris

German HRS network (operational and planned)

Hydrogen police cars at a London HRS

Hydrogen car used at Schaalsee Biosphere Reserve

HRS in Copenhagen: hydrogenlink.net

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This report sets out recommendations for supporting the further commercialisation of hydrogen mobility, based on the findings of the H2ME project

Hydrogen Mobility Europe

- Hydrogen Mobility Europe (H2ME) is a **flagship European project**, deploying hundreds of fuel cell hydrogen cars and vans and the associated refuelling infrastructure, across 8 countries in Europe.
- As part of the project, **more than 1,400 vehicles and 49 hydrogen refuelling stations** will be deployed by 2022 (see next page).
- The project is being supported by the European Union through the Fuel Cells and Hydrogen Joint Undertaking (FCH JU). This support is matched by **significant financial commitments from leading vehicle manufacturers and infrastructure developers**.

Overview of this report

- One of the key aims of the H2ME initiative is to analyse and summarise the findings and lessons learned as a result of the deployment activities during the project, in order to provide guidance for Member States and industry stakeholders in developing and implementing their own plans for hydrogen mobility.
- This report provides an overview of the status of hydrogen mobility in Europe and outlines some of the key barriers to its wider adoption, based on the findings of industry partners and the analysis carried out as part of the project (the results of which can be found in previous reports). Recommendations to address the barriers and thus support the further commercialisation of the technology are then set out, including considerations for deployment, maturing the supply chain, and for the development and implementation of government policy.
- This document builds on the previous public iterations of this report, published in 2017 and early 2020.

H2ME initiative (2015 – 2022)
Project overview

HRS: Hydrogen Refuelling Station
lectric Vehicle **FCEV**: Fuel Cell Electric Vehicle
RE-EV : Range-Extended E

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New hydrogen refuelling stations:

- **20** - 700bar HRS in Germany
- **11** - 350bar and 700bar HRS in France
- **11** - 700bar HRS in Scandinavia
- **6** – 350bar and 700bar HRS in the UK
- **1** - 700bar HRS in NL

Fuel cell vehicles:

- **500** OEM* FCEVs
- **900** fuel cell RE-EV vans

Hydrogen rollout areas:

- Scandinavia, Germany, France, UK, The Netherlands

Observer coalitions:

- Belgium, Luxembourg, and Italy

Industry observer partners:

- Audi, BMW, Nissan, Renault, Renault Trucks, AGA, OMV

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Proposed HRS locations under H2ME-1 (2015-2020) (yellow)
Proposed HRS locations under H2ME-2 (2016-2022) (orange)

*OEM: original equipment manufacturer

Overview of progress

Executive Summary

1. Introduction

2. Progress in commercialisation

3. Barriers to wider adoption of hydrogen mobility

4. Recommendations

- Overview
- Recommendations for deployment
- Recommendations for maturing the supply chain
- Recommendations for future policy and funding

Over two thousand hydrogen vehicles have been deployed in Europe, including cars, vans, buses and trucks

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Number of hydrogen vehicles operating in Europe (approx. in summer 2020)

Vehicles	Germany	France	UK	Nordic region	BeNeLux region	EUROPE
Cars	750	180	200	300	300	**1,700+**
Vans (including range extended vans)	20	196	45	1	5	**260+**
Buses	24	17	20	10	15	**80+**
Trucks	1	-	2 refuse trucks	4	3 refuse trucks 1 27t truck; 1 40t truck	**12**
Trains	2	-	-	-	-	**2**

Plans for further deployment of hydrogen vehicles

- Taxi company Hype plan to deploy 600 hydrogen taxis in Paris by the end of 2020
- By the mid-2020s, hundreds of buses will be deployed across Europe, as part of projects funded by the FCH JU and various national initiatives
- 16 heavy duty trucks and 15 refuse trucks will be put in operation in European cities as part of the H2Haul and REVIVE projects respectively
- 1,600 Hyundai fuel cell trucks to be deployed in Switzerland by 2025
- Plans are underway for hydrogen trains to be deployed across Europe, e.g. Germany, UK and France

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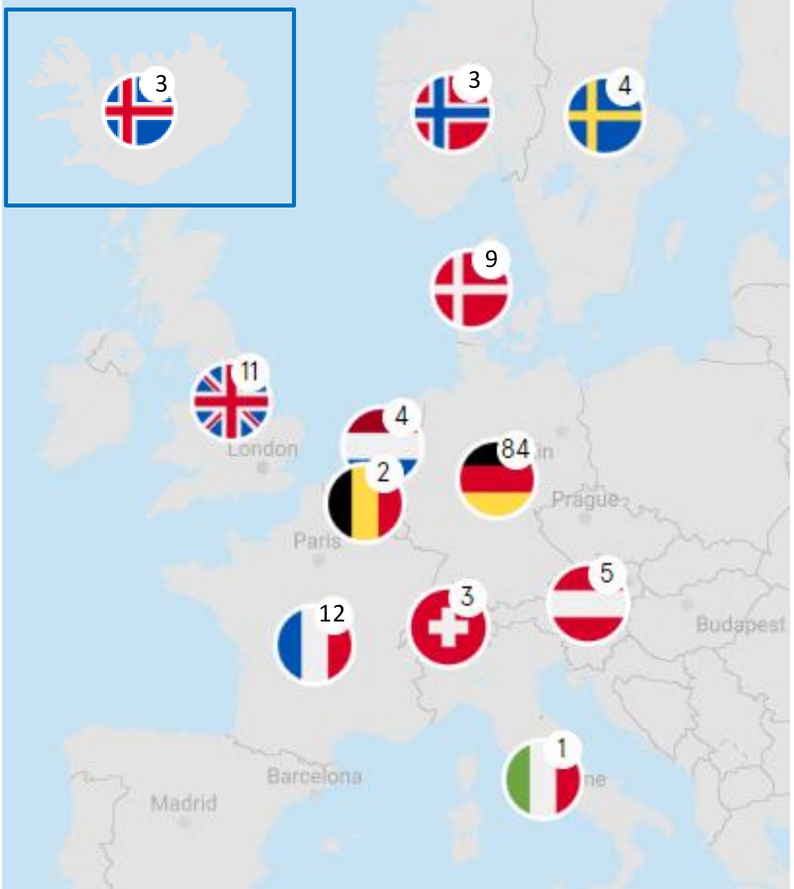
The hydrogen refuelling network in Europe is growing steadily, with over 100 stations installed

- Hydrogen Europe's Technology Roadmap sets a target of **1,000 public hydrogen refuelling stations (HRS) across Europe by 2025**.
- **Rapid acceleration in the deployment of new HRS** over the next 5 years will be required to achieve this: as of July 2020, there were over 130 public operational HRS in Europe, most of which are installed in Germany, France, the UK and Denmark. A further 81 stations are currently planned or under construction.
- While this represents the start of a pan-European refuelling network, **many of the existing stations currently only have the capacity to refuel relatively small numbers of light duty vehicles** (i.e. cars and vans), with only a few stations having the capacity to serve fleets of taxis, buses or other high-demand vehicles.
- **Significant further investment is required** to provide a sufficient network of refuelling stations to meet the potential needs of the hydrogen mobility market, especially when considering the adoption of heavy duty hydrogen vehicles such as trucks, which will also require national networks of high-capacity refuelling stations.

Operational public HRS in Europe (July 2020)



Map of operational hydrogen refuelling stations as of July 2020. Source: H2Live [1]

[1]French number has been edited to reflect the additional 350 bar refuelling stations. Note that there are many additional private HRS in France (29 HRS in total)

New national and regional level approaches, combined with private sector initiatives, are driving the continued development of hydrogen mobility

Emerging approaches to developing hydrogen mobility

- While FCEV and HRS deployment continues to expand, **roll-out of public infrastructure and vehicles has been slower than was planned in 2015**. The level of ambition of the initial strategies exceeded the sector's capacity to deliver on these aims, with strong competition for vehicle availability from global markets outside Europe, combined with various challenges in identifying and securing sites for refuelling stations in urban centres delaying the roll-out.
- In the absence of high volumes of FCEV passenger cars in Europe, hydrogen mobility initiatives (both nationally and at the European level) are increasingly converging on the following approaches:
  - Continued targeting of end users that require the specific operational advantages that hydrogen mobility can provide, where attractive business cases for hydrogen vehicles are now emerging (including **taxis and heavy vehicles, particularly in countries with high taxes for fossil fuel vehicles**).
  - Developing **viable clusters of stations in key locations** where the redundancy and convenience of multiple stations increases the attractiveness of fuel cell vehicles to fleet operators. Within these clusters, and to justify development of new clusters, **demand aggregation activities** (e.g. via letters of intent or fuel purchase agreements from customers near potential refuelling locations) are used to strengthen the business case for new stations and attract investment. Installing small, low-cost HRS in regions with larger existing stations, and/or on motorways between existing "clusters" could be a cost-effective way to improve network coverage for passenger cars.
  - **Deploying heavy vehicles (e.g. buses, refuse trucks) as well as high demand car applications (e.g. taxis)** to help scale up hydrogen demand and the development of infrastructure supply chains in advance of mass passenger car roll-out. **Achieving larger scale hydrogen ecosystems** (i.e. involving numerous vehicle types) is seen as key to reaching the scale of demand to make station operation economic. As such, some cities and HRS operators are considering the potential benefits and requirements of dual-purpose refuelling stations, i.e. allowing cars to make use of refuelling facilities for heavy vehicles such as buses and refuse trucks. This approach could offer business case advantages for HRS operators while demand increases.
  - Alongside the national and regional approaches, numerous **deployment initiatives led by the private sector** are emerging, at local as well as national scales (for example the taxi deployments in Paris and the Swiss trucks scheme). These initiatives have been demonstrated how with scale and ambition it is possible to deploy hydrogen economically. This in turn has led to policy frameworks that support ambitious scale-up plans.

Hydrogen strategies for energy system decarbonisation are now emerging across Europe, and mobility is seen as a key aspect of developing the wider hydrogen economy

National and European hydrogen strategies

National and regional strategies

In the past two years, numerous national hydrogen strategies have been released which have emphasised the role of hydrogen in delivering the transition to net-zero energy economy, and the potential benefits of deploying hydrogen technologies at scale for applications such as industrial energy, transport applications (including marine and aviation as well as road transport) and heating.

The development of hydrogen for mobility is seen as playing a key early role in facilitating the ramp up of the supply chain and skills needed to deliver the wider hydrogen economy. To support this all of the national strategies set out ambitions and funding commitments to support the development of green hydrogen production and the refuelling infrastructure needed to enable vehicle uptake. Often these strategies assume hydrogen transport will begin with heavier duty bus, truck and rail transport. A few examples are set out below; many other countries and regions across the world have released or are developing hydrogen strategies.

- **France:** National Hydrogen Plan (French Government, 2018)
- **Germany:** National Hydrogen Strategy (German Government, 2020)
- **Norway:** Norwegian hydrogen strategy (Norwegian Government, 2020)
- **Netherlands:** Government Strategy on Hydrogen (The Netherlands Government, 2020)
- **Iceland:** 2030 vision for H2 in Iceland (Icelandic New Energy, 2020)

Strategy and funding at European level

- The European Commission released *A hydrogen strategy for a climate-neutral Europe* in July 2020, as part of the European Green Deal (a policy package intended to deliver net-zero by 2050). The strategy objectives are consistent with the national strategies, setting out the investments required to deliver the hydrogen economy, as part of a sustainable economic recovery from Covid-19 impacts.
    - Where previously, European funding for hydrogen activities had been largely contained within the Fuel Cells and Hydrogen Joint Undertaking, support for hydrogen technologies will now be integrated within all packages in the Green Deal, with funding to be made available across transport, industry, heat and wider energy system applications. Targets for renewable hydrogen in specific end-use sectors will also be considered as part of future European policy measures.

Barriers to wider adoption of hydrogen mobility

The following slides summarise the main barriers to further FCEV commercialisation, based on the experiences of the partners in the H2ME projects

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Evidence base for the barriers

Conclusions regarding the main barriers to the further commercialization of hydrogen mobility are set out in the next slides. These conclusions are based on the experiences of the hydrogen industry stakeholders participating in the H2ME projects (shown below), as well as on the analysis carried out as part of the H2ME project. The basis for the conclusions includes:

- Experiences gained from the deployment of over 1,000 hydrogen cars and vans, and over 130 public HRS across Europe (see pages 10-11), and data collected on the performance and customer responses of these vehicles and HRS in operation.
- Project partner experiences of activities relating to other hydrogen mobility applications (including trucks and trains).
- Customer surveys carried out as part of H2ME projects and the ZEFER project (which focuses on fleet deployment of hydrogen cars), gathering feedback on the improvements required for further FCEV adoption by fleets and business users.
- Workshops and bilateral interviews with the stakeholders below and with others outside the H2ME projects.
- Techno-economic analysis of HRS and FCEV business cases.

The detailed analysis of these topics can be found in the public reports previously prepared as part of this project.

Although significant progress has been made, the number of refuelling stations is still a major barrier to further adoption of FCEVs

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HRS deployment barriers to FCEV adoption:

- **Number of local HRS (i.e. in hydrogen demand "clusters")**
  - A minimum of two HRS per cluster is required to establish demand from light fleet applications; this provides redundancy (allowing HRS maintenance to take place) as well as additional geographic coverage.
  - Some high-mileage light duty fleets need more operational flexibility; to support a higher replacement rate in these fleets, more local HRS are required to provide a greater degree of city-wide coverage.

- **Wider HRS coverage (to enable long distance journeys)**
  - Many business customers (as well as private customers, and some fleets) rely on the ability to make long journeys. In addition, some fleets frequently operate in suburban or rural areas which are not covered by current HRS locations, which tend to be closer to urban centres. In practice, in the initial stages of HRS deployment, this trend is likely to restrict the accessible market for cars and vans to those that are "captive" operating within a region well served by HRS.

- **Some HRS have limited capacity, performance or interoperability**
  - Some HRS deployed several years ago are not designed to meet the level of demand from recently deployed local fleets, and need to be replaced or upgraded; in addition some relatively recent HRS can only refuel at 350 bar. This means that for some vehicles, the available public infrastructure does not enable the full capabilities of the technology to be realized (either due to refuelling demand exceeding HRS capacity, or due to vehicles that can refuel up to 700 bar only obtaining a partial refuel, or in some cases being unable to use 350 bar HRS). This further restricts the locations where FCEVs can be deployed with an optimal user experience, and risks lowering user confidence in hydrogen as a fuel.

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Siting and permitting is a bottleneck in the HRS installation process, and the high risk associated with investment also needs to be addressed

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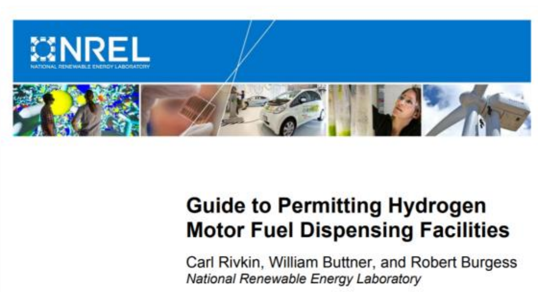
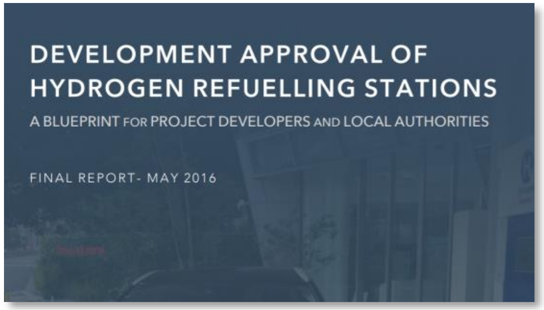
Issues to be addressed to accelerate HRS deployment:

- **Siting and permitting challenges**
  - The time taken to identify sites for HRS and delays at the permitting stage are major factors that have contributed to the deployment of new HRS being slower than envisaged by national strategies. Work is required to educate and improve sharing of best practice between authorities responsible for consenting and approving new hydrogen refueling stations.

- **High investment risk for HRS operators and green hydrogen producers**
  - Uncertainty around long-term demand creates risk for investors in new HRS and green hydrogen production.
  - For existing sites, when utilisation is low, the high cost of maintaining and operating HRS creates a risk that stations will close if there is no ongoing support.
  - Uncertainty around the timings of centralised large-scale low carbon hydrogen production (e.g. at the scale envisaged for the use of hydrogen in heat and industrial applications) also creates a demand risk for short-term, smaller scale green hydrogen production routes: if there is a possibility of larger scale lower cost hydrogen production arriving, the business case for smaller scale (often higher cost) production options becomes challenging.
  - For trucks, lack of certainty around refueling technology choices (refueling pressure at 350bar vs 700bar, and gaseous vs liquid) is also holding up progress.

HRS permitting guidance document from the US National Renewable Energy Laboratory (2016) and a blueprint for approvals from the Carbon Neutral Cities Alliance (2016)





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Limited vehicle availability and high ownership costs are also barriers to wider adoption of FCEVs

Cost and availability barriers to FCEV adoption:

- **Model choice is limited and suitable hydrogen vehicles are not available for all potential customers**
  - To enable wider adoption in different markets, significant increases to the available model choices are needed, including more options for cars and in particular vans, as well as heavy trucks (note that fuel cell trucks are not yet readily available in Europe outside of specific demonstration project initiatives).

- **The cost of FCEVs and hydrogen can be prohibitively high for many potential end users**
  - Current cost premiums for FCEVs (relative to the cost of petrol and diesel vehicles) are prohibitively high in the absence of funding (although in specific use cases the total cost of ownership can be close to that of petrol or diesel, after subsidies).
  - If the fuel cost per km *as seen by the end user* is comparable to fossil fuel equivalent, the cost of hydrogen does not present a barrier to adoption. However, at the low levels of demand currently seen at public HRS in Europe (<200kg/day) the cost of producing and supplying hydrogen at an HRS can be very high; if this cost is passed on to end users, this leads to a significant fuel cost premium compared to fossil fuels, which could be a barrier to adoption. In addition, the "per kg" costs of maintenance for HRS to achieve high availability are significant at low levels of demand.

Examples of some popular petrol and diesel vans and trucks used across Europe; a wider range of hydrogen models would increase the accessible market size.

Demand uncertainty contributes to the lack of model choices and high costs; national policy-makers can provide clear market signals to help address this

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Issues to be addressed to bring costs down and improve availability:

- **Manufacturers have insufficient certainty around demand volumes needed to produce attractively priced vehicles for some market segments**
  - Particularly in the heavy vehicle market, vehicle costs with low production volumes are too high to justify making hydrogen models available at attractive prices, and OEMs are reluctant to produce more vehicles at risk. Demand aggregation (e.g. supported by pre-orders) for each model / type is needed to demonstrate the demand and unlock economies of scale.
  - This type of demand-based business case can be combined with market conditions that make FCEVs more attractive e.g. high taxes or restrictions for diesel. Long-term policy mechanisms (e.g. per vehicle subsidies maintained over a certain time period) are needed to increase market confidence (for manufacturers and customers) and reduce risk. This also applies to hydrogen production and HRS operation; hydrogen subsidies or other mechanisms that can provide more certainty around long-term demand and revenues will make the investment case much more attractive for HRS operators.

Hyundai is not currently a major supplier to the European truck market but has responded to the demand for zero emission trucks in Switzerland and other European countries: the Hyundai Hydrogen Mobility project plans to deploy over 1,600 fuel cell trucks in Europe by 2025. This project has been made possible by aggregating demand from numerous transport and logistics fleets in Switzerland, combined with high taxes for fossil fuel Heavy Good Vehicles (HGVs).

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A fully integrated regulatory framework that reflects the safety of hydrogen in mobility applications is needed to avoid restrictions to future adoption of the technology

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Safety-related issues for FCEV adoption:

- **FCEV users across several countries have experienced access restrictions for hydrogen vehicles**
  - Several users in the H2ME project reported that they were prevented from using underground parking, tunnels or ferries with their FCEV. If this continues to be an issue, this could become a significant barrier for the wider adoption of the technology. Further evidence and understanding of FCEV safety in enclosed spaces is needed.
- **Some users have expressed concerns around the safety of the technology**
  - Whilst the majority of FCEV users in the H2ME project did not express concerns about the safety of the vehicles, some did, most commonly relating to the high-pressure systems in the vehicles and the risk of potential explosions.
- **Safety incidents at hydrogen stations could impact availability of hydrogen for customers**
  - In June 2019, there was a fire and a pressure wave at an HRS in Norway due to a hydrogen leakage. The immediate incident was managed quickly. However, the investigation of the root causes took several months and during this time, all HRS with the same design were closed to ensure that no similar incidents would occur. The risk of reduced utility for hydrogen vehicles as a result of this could be a barrier to wider adoption, if not successfully mitigated.

Regulatory issues for FCEV adoption:

- **New research leading to guidance and/or regulations relating specifically to hydrogen mobility still needs to be developed or revisited for several key areas:**
  - Using FCEVs in enclosed spaces such as underground parking, tunnels and ferries
  - Onsite storage of hydrogen at refuelling stations (safety requirements currently relate mainly to industrial sites)
  - Transport of hydrogen by tube trailer
- **There is currently a lack of the knowledge and skills required to ensure that hydrogen regulations are implemented appropriately.**
  - There is a need for further research and education within the supply chain and regulatory bodies, to address the lack of understanding around hydrogen safety. The interpretation and implementation of HRS standards by local planning authorities is just one example of where this is required.

The following slides set out recommendations to support the further commercialisation of hydrogen mobility from three different perspectives

Overview of recommendations

The following slides set out recommendations to address the issues identified above in terms of three key aspects of delivering hydrogen mobility:

1) Recommendations for deployment

- Recommended strategies and actions for coordinating the delivery of future hydrogen vehicles and refuelling stations

2) Recommendations for maturing the supply chain

- Recommended approaches needed within the FCEV and HRS supply chain and the related wider infrastructure

3) Recommendations for policy and funding

- Broad policy and funding requirements to address cost barriers and support the wider commercialisation actions

The recommendations are based on lessons learned from hydrogen industry stakeholders and the analysis carried out as part of the H2ME project, including customer surveys, workshops, interviews, and techno-economic analysis (the results of which can be found in various other public reports).

Hydrogen mobility initiatives should focus on aggregating local demand from various vehicle applications to identify ways to scale up and de-risk hydrogen infrastructure

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Issues to address	Recommendations for hydrogen mobility initiatives

Low numbers of HRS
High investment risk for HRS operators and green hydrogen producers
Limited vehicle model choice
The cost of FCEVs can be prohibitively high
	▪ Continue to **target high utilisation applications** & **link HRS deployment to emerging demand.**
	▪ Focus on **securing commitment** to a rapid scale-up of **hydrogen demand at a local scale** (e.g. within a city or region). This will involve various **demand aggregation** activities:
	  ▪ Identify potential short-term local demand for different applications (i.e. vans, buses, refuse trucks, trains and local logistics applications as well as cars for fleets and business users).
	  ▪ For different vehicle types and uses, compare: **vehicle & HRS costs (relative to incumbent fuels), specifications, and local demand, to identify options which can work best in the local area**. Identify specific local factors required to unlock the levels of demand required for high-capacity, high availability HRS to be deployed and then well utilised: e.g. local vehicle purchase incentives/mandates, a local hydrogen demand commitment and/or funding needed for HRS investment. Look to build a suite of local measures which create demand for a range of vehicle types, which collectively create demand at stations of 100s of kg/day.
	  ▪ Coordinate potential vehicle demand from different end users, and with adjacent regions, to aggregate demand for vehicle procurement: a) to signal demand for **light vehicles** to OEMs (which are often making allocation decisions between Europe, Asia and North America based on expected sales) and b) to instigate supply of **heavy vehicles** to new markets at affordable prices (in the case of heavy vehicles, procurement in the scale of 100s of buses or HGVs in a region could be sufficient under certain conditions).

Siting and permitting challenges	▪ Be aware of the need for **advance planning** for HRS siting, consenting and deployment: total lead time for is likely to be up to two years per HRS based on experiences in Europe to date. ▪ Explore opportunities to use sites owned by local authorities or existing fuel retailers. Once potential sites are identified, **engage with local stakeholders** (planning authorities, site owners, legal teams) as early as possible to ensure the process is collaborative, and to address any issues. ▪ Work with national authorities to put in place clear **national guidance for permitting processes** that can be implemented locally, based on experiences of existing HRS.

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While hydrogen mobility initiatives and policy have shifted towards heavy duty applications, refuelling infrastructure for passenger cars can be developed alongside this

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Hydrogen passenger cars and light duty vehicles will have a role in delivering net zero

Although the focus for hydrogen mobility has largely shifted towards heavy duty road transport applications such as buses and trucks, due to the cost benefits that can be achieved at higher levels of demand, the vehicles deployed in the H2ME project have nevertheless demonstrated that hydrogen passenger cars and vans can offer specific operational advantages over other zero emission options. The ability to completely refuel in under 10 minutes offered by FCEVs is valued highly by certain commercial applications (such as taxis, police services, and utility fleets) and is likely to be a preferred option for at least some private car owners in the future, particularly as the availability of fossil fuel vehicles diminishes in line with net-zero goals. Based on the experiences of the H2ME project, two main approaches to infrastructure deployment can be pursued to ensure that the emissions and operational benefits of hydrogen cars and vans can be realised; a combination of both approaches is recommended.

Issues to address

- **Low numbers of HRS**
- **High investment risk for HRS operators**

Recommendations for hydrogen mobility initiatives

- Where appropriate, ensure that HRS for heavy duty vehicles also have the capability & capacity to refuel passenger cars. This includes consideration of:
  - Location & HRS accessibility
  - Suitable refuelling protocols and dispensers
  - Refuelling capacity
  - Interoperability with other public HRS (e.g. see p16)
- Develop local clusters of stations for light vehicles where there is a clear demand from local fleets with consistently high mileages, such as taxis:
  - Opportunities are most likely to exist in cities with policies providing strong incentives to zero emission fleet operations, and with fleet operators with a clear business case and plans to expand their zero-emission fleet.
  - Taxi fleets have a particularly clear need for rapid refuelling, making FCEVs a strong choice.
  - Station siting should be decided in close consultation with the vehicle operators; FCEV fleet expansion will be facilitated by minimizing the "dead mileage" needed to refuel.
  - Station & network specifications should include redundancy to ensure high availability.

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Recommendations for maturing the supply chain

Hydrogen infrastructure suppliers and operators need to identify priority areas for technology improvement whilst working towards achieving harmonised standards

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Issues to address

- **Some HRS have limited capacity, performance or interoperability**

Recommendations for the hydrogen mobility supply chain

- Ensure that **new stations are future-proofed** wherever possible, e.g. with space and connection points to facilitate upgrades to increase refuelling capacity, updated refuelling protocols, and / or improved monitoring and remote maintenance. **Modular station design** could help to enable this.
- Establish an independent **regulatory body** for HRS at the national level to **test and certify new refuelling stations** for safety and performance, and to maximise the interoperability of the growing networks of public HRS. This may require support from vehicle suppliers & existing HRS operators and is likely to require funding either from government, and/or from within the sector.
- Continue to **improve the customer experience of existing HRS**: including providing high availability, communicating station status, and improving ease of refuelling (e.g. nozzle design).
  - **Detailed data analysis is needed** to understand progress made on availability: specifically the impact of faster maintenance vs reliability of specific components.
  - **Make live data available** to third party mapping providers, to ensure customer have access to data on where stations are open and their ability to refuel vehicles.
  - The industry should seek funding for projects to bring **improvements to the quality and supply of specific HRS components** that frequently need repairing or replacing. Ease of use should also be considered in aspects such as nozzle design.
- **Define protocols for refuelling trucks and other heavy-duty vehicles**, considering lessons learned from light duty vehicle refuelling and buses: protocols and the technologies required to fulfill them can impact HRS cost and reliability, which are both key factors in the rate of FCEV adoption.

Issues to address

- **The cost of FCEVs can be prohibitively high**

Recommendations

- Continue R&D to **reduce production costs for fuel cell and hydrogen components**.
- Ensure **FCEV car and van models** are targeted at fleet markets which can sustain the price points at which the vehicles are sold.
- Work with OEMs to increase production volumes and so drive down the cost of different vehicle types. Where possible Governments can help here by signaling that there will be sustained demand for hydrogen vehicles going forwards.

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The supply chain stakeholders should develop an improved understanding of hydrogen safety in various contexts and communicate this to inform the regulatory landscape

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Hydrogen Mobility Europe

Issues to address

- **Access restrictions for FCEVs**
- **User concerns around safety**

Recommendations for the hydrogen mobility supply chain

- If future access issues are to be prevented, **further work is needed to demonstrate the safety of FCEVs in enclosed environments** to infrastructure operators / regulators, and to ensure that regulations and guidelines enable access for FCEVs in such environments. The HyTunnel-CS project is conducting pre-normative research on this topic; the wider sector should engage with and build on the project's findings, including working to address any safety issues identified as part of this work.
- Clear **communication and dissemination of the evidence base** for FCEV safety (including in confined spaces as well as in the case of accidents) will be needed:
  - To ensure that FCEV access restrictions are only imposed when identified when strictly necessary for safety purposes;
  - To ensure that public awareness of the relative safety of hydrogen mobility improves.

Issues to address

- **Safety incidents can lead to temporary closure of multiple similar HRS**

Recommendations for the hydrogen mobility supply chain

- Aim for **increased diversity of technology design within HRS clusters** to ensure that in the event of an incident, local hydrogen availability is not adversely affected by precautionary close-downs.
- Minimise the risk and impacts of incidents by **following best practices for safety**, including:
  - Conducting rigorous risk assessments at the design stage and ensuring designs take account of these assessments, as well as the well-respected hydrogen station design standards.
  - Implementation and documentation of thorough internal safety processes and checks for HRS assembly, commissioning and maintenance.
  - Training internal emergency response teams, including defined procedures to be followed in the event of an incident.
  - Ensuring that risk assessments and mitigation processes at the design stage account for the impacts of temperature variations.
  - Avoidance of "overdesign" of components: faults in equipment should be identifiable at the testing stage (i.e. early failure rather than late failure).

FCH

Recommendations for policy and funding

National policy and funding can provide the market certainty and cost support needed to accelerate the next stage of hydrogen transport commercialisation in Europe

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Hydrogen Mobility Europe

Issues to address

- **Low numbers of HRS**
- **High investment risk for HRS operators and green hydrogen producers**

Recommendations for future policy and funding

- Implement policy at national level that **de-risks the business case for HRS operators** to produce low cost, low carbon hydrogen and invest in new HRS. This could involve: 1) Continued availability of **grants or cheap finance** for initial infrastructure investments; 2) in the longer term, a move to **support hydrogen on a "per unit sold" basis**. This type of support for biofuels and renewable energy has led to these low carbon energy options becoming mainstream as part of mature markets. **Subsidies or certificate schemes to incentivise green hydrogen sales** over a given time period can provide some degree of revenue certainty to make investment attractive.
    - The implementation of the Renewable Energy Directive II (which includes the use of renewable hydrogen for mobility) offers a pathway for the introduction of support schemes for hydrogen at a member state level. This (or other bespoke hydrogen subsidy schemes) can help unlock the market for hydrogen deployment.
    - Overly restrictive requirements (e.g. stipulating 100% additional "new" electricity) could limit the potential for such schemes to support hydrogen roll-out. The European level **definitions of renewable hydrogen should be designed with sufficient flexibility** to enable support for affordable hydrogen production from a range of renewable resources.
    - National implementation should: a) guarantee access to support for early investors for a reasonable time period; b) consider volume caps on renewable hydrogen to ensure that it does not dominate the RED II targets; c) provide clarity on the inclusion of biomethane reformation and waste gasification, which could compete with efforts to decarbonise heat.
- Encourage **collaborations between vehicle providers and HRS investors** which can increase the scale of deployment: for example, the taxi initiative in Paris (HysetCo) or the truck deployment project in Switzerland (Hyundai Hydrogen Mobility). Where possible, provide specific incentives which are aimed at catalyzing the progression to such larger scale initiatives.
- Provide funds to **initiate collaboration and strategy development** between government and industry in countries (and regions) with nascent interest in hydrogen mobility.

FCH

Policy and funding for FCEVs will be needed until critical volumes are reached, and approaches can be informed by the success of various policies for electric vehicles

Issues to address

- **The cost of FCEVs can be prohibitively high**
- **Limited vehicle model choice**
- **Lack of market certainty**

Recommendations for future policy and funding

- In parallel to the above, national and European policy should set clear targets for uptake of zero emission vehicles and introduce further **measures to encourage manufacturers to supply more zero emission options across different vehicle segments**, as well as **ensuring that FCEVs are attractive to customers** (financially and otherwise). Measures such as the examples shown below will increase market confidence for manufacturers, customers and infrastructure investors.
  - Sufficient funding for **subsidies to cover cost premiums for fuel cell vehicles** over petrol / diesel alternatives, until critical volumes and price points are reached. Based on the electric vehicle market, the most effective zero-emission vehicle (ZEV) subsidies are: available close to the point of sale; locked into place for at least several years; relatively simple for consumers and dealers to understand their value, and widely accessible.[1]
  - **Restrictions on fossil fuels**, e.g. within: Zero Emission Zones, public procurement, taxi fleets.
  - The **ZEV credit market** in California has played an important role in development of ZEV technology amongst numerous car manufacturers; to improve on this approach, future credit markets could **target (or provide extra credits) for ZEV sales within specific market segments** where emissions reductions and new vehicle technology development are most needed (including those well-suited for FCEV use).[2]

[1] ICCT, Principles for effective electric vehicle incentive design, 2016. [2] RFF, California's evolving zero emission vehicle program, 2019.

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Abbreviations

BEV	Battery Electric Vehicles
FCEV	Fuel Cell Electric Vehicle
H2	Hydrogen
H2ME	Heavy Good Vehicles
HGV	Hydrogen Mobility Europe (project)
HRS	Hydrogen Refuelling Station
R&D	Research and Development
RE-EV	Range-Extended Electric Vehicles
RED II	Second Renewable Energy Directive
ZEV	Zero-emission vehicle