Towards a comprehensive hydrogen infrastructure for fuel cell electric cars in view of EU GHG reduction targets

ECN – Marcel Weeda (weeda@ecn.nl), Hein de Wilde
LBST – Reinhold Wurster (reinhold.wurster@lbst.de), Ulrich Bünger
Sweco – Geert Schaap (geert.schaap@sweco.se), Cecilia Wallmark
RWS – Floris Mulder (floris.mulder@rws.nl) – HIT coordinator

Abstract

This paper outlines the value of hydrogen fuel cell electric vehicles (FCEVs) and the status of the required hydrogen refuelling infrastructure development in the context of the EU's alternative fuels infrastructure ambition (as expressed in the Alternative Fuels Infrastructure Directive[1], AFID) and the national policy frameworks which are part of this. The zero-emission capabilities of fuel cell powertrains is addressed as well as the potential to extend these in a well-to-wheel perspective when producing hydrogen from renewable or carbon-free energy sources. A detailed overview is given of the state-of-the-art of FCEVs and their deployment into the market, including the deployment of a sufficient number of hydrogen refuelling stations (HRSs) in the first key markets in Europe. The HIT (Hydrogen Infrastructure for Transport) project, funded by EU's Trans European Network for Transport programme (TEN-T), is briefly presented including a description how it can contribute to a harmonized HRS roll-out in countries that choose to include hydrogen in their national policy frameworks. Finally current policies and rollout strategies are investigated and described in order to see how they can facilitate a timely roll out of fuel cell vehicles, so the EU can achieve its emission reduction targets for transport. Preliminary conclusions are:

- To reach EU GHG emission reduction targets for transport by 2050 biofuels, renewable methane, electricity, and hydrogen will need to be applied wherever possible. Even the most advanced ICE (Internal Combustion Engines) technologies will NOT be sufficient to meet this target by far.
- FCEVs are becoming available in growing numbers and HRS networks are gradually being established. A better coordinated deployment of vehicles and infrastructure in Europe is needed in order to secure these vehicles for the European market.
- HRS rollout will already be required in sufficient numbers in the early phases, in order to achieve acceptable area coverage. Due to the initially low number of vehicles, these HRSs will however remain underutilized in the beginning and will need innovative business models and support. Support mechanisms are also needed for FCEV purchases before the mass production phase is reached.
- Successful instruments in the market introduction phase are: the participation of local/regional and national authorities in public private partnerships (as in the EU), direct funding for FCEVs and HRSs (as in Norway and Japan) and stringent technology-oriented zero-emission vehicle policies (as in California).

[1] Clean Power for Transport: A European alternative fuels strategy, 2014/xx/EU, Brussels, 29.09.2014 http://ec.europa.eu/transport/themes/urban/cpt/index_en.htm

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The challenge

The EC has indicated the need to reduce CO_2 emissions in transport by 60% in 2050 compared to 1990 (i.e. even 70% reduction compared to today)[2]. Even the most advanced ICE technologies will not be able to meet this target over the whole vehicle population by far. Consequently, alternative very low CO_2-technologies will need to be applied wherever possible. Basically four low CO_2-technologies are available: biofuels, renewable methane, electricity, and hydrogen. Since it is very complicated to apply electricity and hydrogen in aviation and long haul trucking, these modes will most likely need all biofuels available, or would need power-to-liquid fuels[3] or to some extent would remain dependable on fossil fuels (kerosene/diesel and LNG) at least for a significantly longer timeframe than in passenger vehicles. Thus in order to reach the overall transport CO_2-reduction, the light duty sector needs to cut its emissions to almost zero by 2050. This implies that even by 2035, all new light duty sales need to be electric or hydrogen vehicles (the current EU ambition according to the same White Paper is CO_2 free logistics in major urban areas by 2030).

Hydrogen and electricity are considered the main options to deliver a significant contribution to long-term oil substitution in transport, and to the reduction of carbon dioxide (CO_2) and air polluting emissions in this sector[4] (Expert Group Alternative Fuels).

Electric vehicles have their cost-benefit optimum in the smaller vehicle segment and driving ranges below approximately 150 km. This makes them especially suited for urban areas, indicatively allowing approximately 50% of the 2050 light duty vehicle (LDV) fleet to be electric. Fuel cell electric vehicles (FCEVs) are also suitable for larger cars and driving ranges over 500 km, making them the most attractive option for the remaining 50% of the LDV segment in 2050. This segment, although only half of the LDV population contributes about 75% of the CO_2 produced by the LDV fleet.[5]

Assuming as a baseline for the four HIT countries investigated (DK, FR, NL, SE) and the two benchmark countries (DE, UK) with a total number of conventional vehicles of about 116 million, that the six markets develop similarly, figures analysed for an OEM-rollout of FCEVs in Germany[6] are applied and extrapolated. Following these assumptions, in 2020 annual car sales of approximately 200,000 FCEVs and cumulative car sales of 1.2 million will be reached. In 2030 annual sales of approximately 400,000 and cumulative sales of 3.2 million will need to be reached.

In addition to these technical and market challenges there is the political and policy challenge to integrate hydrogen into the national policy frameworks which are required under the AFID. The AFID requires that Member States have to establish national policy

[2] White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144 final., Brussels, 28.03.2011
[3] Power-to-liquid (PtL): electricity-based synthetic hydrocarbon obtained via synthesis of hydrogen with a carbon carrier where the hydrogen is obtained via electrolysis operated with renewable electricity
[4] 2011 report of the Expert on Future Transport Fuels supported by DG MOVE
[5] A portfolio of power-trains for Europe: a fact-based analysis - The role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles, McKinsey & Company, December 2010, page 42
[6] Propfe B, et al., Market penetration analysis of electric vehicles in the German passenger car market towards 2030, International Journal of Hydrogen Energy (2013), http://dx.doi.org/10.1016/j.ijhydene.2013.02.049

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frameworks in which they describe their national targets and aims and the supportive actions it takes to develop the market for alternative fuels, including the deployment of the necessary infrastructure. All of this to be developed in close cooperation with local/regional authorities and the involved industries.

The present paper investigates and describes the context described above to establish if the actual policies and rollout strategies will enable that the required 2030 market sales can be reached in time.

Value of hydrogen powered electric driving

Hydrogen is the fuel for electric vehicles that are equipped with a fuel cell system instead of a battery system [7] and for battery electric vehicles that are equipped with a fuel cell range extender. The fuel cell uses hydrogen in a clean and silent manner. Water vapour is the only by-product. FCEVs are thus one of only two truly zero-emission vehicle options, i.e. locally, at vehicle level, they emit no CO_2 or air pollutants. The other truly zero-emission option is the full battery electric vehicle.

Electric vehicles are propelled by an electric motor as primary drivetrain. This motor is operated by electricity. In the case of propulsion through fuel cells and hydrogen, the electricity is produced by an electro-chemical reaction of hydrogen with oxygen with heat and water as by-products.

But there are more features that make FCEVs an attractive proposition. The vehicles combine the comfort and benefits of smooth and silent electric driving with the convenience of conventional cars in terms of size, vehicle range and refueling time. Hydrogen is stored at high pressures in the vehicles. Car manufacturers have agreed on a standard of 70 MPa for passengers cars [8]. As a result, enough energy can be stored in a tank to allow travel in the order of 500 km or more. Furthermore, current state-of-the-art HRSs allow FCEVs to be refueled completely in approximately 3 minutes. Due to the fact that hydrogen is compressed to 70 MPa (700 bar) and contained in a carbon fibre composite tank onboard, the FCEV has a significantly higher power density and lower powertrain system weight than any available advanced lithium ion battery vehicle. The FCEV is only slightly heavier than a comparable internal combustion engine (ICE) vehicle.

The hydrogen and fuel cell combination is suitable to power a wide range of vehicles, from small cars for short distance driving, larger cars for longer distance driving to city buses and small to medium range trucks, while drastically reducing engine noise at lower speeds.

If hydrogen is produced from a carbon-free energy source such as solar or wind electricity via an electrolysis unit (splitting of water by an electric current into hydrogen and oxygen),

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[7] The fuel cell system serves as primary source for provision of electricity to the electric motor, instead of a battery system. A small battery will however be included in the powertrain of a fuel cell vehicle to be able to store electricity from regenerative braking and for fast power supply in situations of peak power demand.

[8] Buses are less constrained in space for storage tanks. Therefore, a lower pressure level can be applied to buses while still being able to store enough energy for a sufficient vehicle range. Typically, 35 MPa is used for buses.

a FCEV obtains zero-emission characteristics from a well-to-wheels perspective (only battery-electric vehicles have the same characteristics). In this case the energy efficiency is approximately double that of ICE and hence 50% more fuel resource efficient.

Hydrogen and electricity are complementary energy carriers. The production of hydrogen from water via electrolysis using renewable electricity offers a mechanism for energy and electricity storage and hence for a flexible integration of intermittent renewable electricity sources (such as solar and wind) into the energy system. In this manner hydrogen has the function of storing energy. The stored hydrogen can be used for several end-uses, such as a clean fuel for FCEVs, as a raw product for the chemical industry or it can be fed back into the grid during peak hours (against peak-hour prices). Hydrogen from electricity is therefore capable of reducing Europe's dependence on imported fossil fuels thus increasing energy supply security. This increases the utilization rate of our growingly renewable electricity-based energy systems and thereby contributes to fulfilling Europe's greenhouse gas emission reduction goals.

In the short-term hydrogen will be mostly fossil based, using either low cost chemical by-product hydrogen (where available for initial markets) or hydrogen obtained through steam reforming of natural gas (SMR). Both options could already provide the opportunity for significant GHG (Green House Gas) emission reductions. Compared to most modern diesel cars, an FCEV operated with hydrogen obtained from natural gas via SMR can achieve at least 20% lower GHG emissions. Using chemical by-product hydrogen (depending on the electricity mix used for the chlorine electrolysis) in a FCEV stands for GHG emissions equal to a diesel car or of a compressed natural gas (CNG) vehicle or lower. In areas where biomass is available in sufficient amounts and sustainably produced (e.g. without negative indirect land-use change impacts or competition to food production), the feedstock flexibility of hydrogen can be enhanced by either gasification of biomass or by reforming biogas to hydrogen.

Status of deployment of FCEVs and HRSs

FCEV and HRS planning for selected regions/ countries

In several forerunner regions, public private partnerships (PPPs) have been established for the deployment of FCEVs and HRSs. The aim is to share the early investment risks of establishing an initially heavily underutilized and hence costly hydrogen refuelling infrastructure. Such infrastructure needs to be available as a precondition for selling the first FCEVs to customers. The most prominent initiatives worldwide are the California Fuel Cell Partnership in the USA (CaFCP); the Clean Energy Partnership CEP (until 2016)/ H_2 Mobility (from 2014 onward) in Germany; the Copenhagen Hydrogen Network (CHN) in Denmark; the Fuel Cell and Hydrogen Joint Undertaking FCH 2 JU in the EU; H_2 Mobility France; HyOP in Norway; the Research Association of Hydrogen Supply/Utilization Technology HySUT in Japan; and H_2 Mobility UK. HyOP, H_2Mobility Germany, CaFCP and HySUT are organisations which are either already joint ventures or have a government mandate directing the HRS rollout in their respective countries. See below for an overview of the FCEVs and HRSs planning for selected regions and countries.

*Overview FCEVs and HRSs planning*** for selected regions and countries*

	California[9]	Denmark[10][11]	France[12]	Germany[13][14]	Japan[15]
Fuel cell cars	2014: 125 2017: 6,650* 2020: 18,465*	2014: 17 2025: 5/100,000 2035: 700,000 2050: 1,400,000	2014: <50 2020: 17,000 2025: 185,000 2030: 790,000	2014: ~ 110 2015: <5,000 2020: 150,000 2030: 1.8 mln	2014: 41 2015: 1,000 2020: 100,000 2025: 0.5-1 mln
HRS (all public)	2014: 17 2015: 23 2016: 51 2018: 68 2024: 100*	2014: 3 2015: …10 2025: 100-200 2050: 500-1,000	2014: 0 2015: <10 2018: 30-35 2020: 50-60 2030: 600-650	2014: 16 2015: 50 2017: 100 2025: 450 2030: 1,000	2014: 19 2015: 100** 2020: 2025: 1,000
	Netherlands	Norway[16][17]	Sweden[18]	South Korea[19][20]	UK[21]
Fuel cell cars	2014: 2 2015: few 2020: 1,500 2025: 15,000 2030: 125,000	2014: ≤20	2014: 3 2015: few 2020:	2014: 100 2015:< 5,000 2020: 50,000	2014: 10 2020: 10-15,000 2030: 1.6 mln
HRS (all public)	2014: 2 2015: 3-4 2020: 20 2025: 80 2030: 200	2014: 5 2015: 7 2017: 17 2020: 25	2014: 1 2015: 4 2020: 15	2014: 13 2015: 43 2020: 200 2030: 500	2014: 9 2020: 65 2025: 330 2030: 1,150

*) FCEV number projections by CARB, HRS funding allocated until 2024

**) 100 HRSs to be installed by 03/2016 (end of FY2015). Toyota Tsusho/ Air Liquide build 3 HRSs in 2014. JX Nippon to build 40 HRSs before 03/2016 and 100 HRSs before 03/2019

***) The status of the planning is different for the various mentioned plans.

[9] A California Road Map - The Commercialization of Hydrogen Fuel Cell Vehicles; CaFCP, July 2014
[10] HIT NIP | Denmark – National Implementation Plan for Hydrogen Refuelling Infrastructure, 2nd draft edition, Hydrogen Link, March 2014
[11] Brint til Transport I Danmark frem Mod 2050, Baggrundsrapport, Hydrogen Link, December 2011
[12] National Implementation Plan for France, Element Energy, 12th March 2014
[13] Strategic Approach to Integrate National and European Funding Programs for a Harmonized Build-up of a European H2 Infrastructure, J. Pallasch and H. Butsch, NOW, 3rd July 2014
[14] H_2-Mobility - Preparing for a Hydrogen Infrastructure in Germany, K. Bonhoff, NOW, Berlin, 20th March 2012
[15] Country Update Japan, 21st IPHE SC Meeting Oslo, Norway 20th May 2014
[16] Personal communication, HyOP, Ulf Hafseld, 20th May 2014
[17] Hydrogen Infrastructure in Norway, IPHE Oslo, HyOP, Ulf Hafseld, 20th May 2014
[18] HIT-1 Fact based analysis for a national implementation plan, Sweden, Sweco, 5th March 2014
[19] Status of HRS in Korea, 20th September 2012
[20] Hydrogen and Fuel Cells in Korea, Yong-Gun Shul, 21st IPHE SC Meeting Oslo, Norway, 20th-21st May 2014
[21] UK H_2Mobility – Phase 1 Results, April 2013

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Availability of FCEVs

One large automotive manufacturer, Hyundai from South Korea, already offers FCEVs to commercial customers on a lease basis for a maximum of five years in California, Korea and Europe, claiming in the earning of credits as a major motivation, particularly in California. Since 2013, Hyundai has been manufacturing a 1,000-FCEV lot in their automated conventional assembly line in Ulsan. By 2015, Toyota and Honda have each announced that they will offer approximately 1,000 FCEVs per year. Also Hyundai plans to ramp up production as a next step and introduce a new FCEV presumably with effect from 2016. Starting in 2018, an alliance comprising Daimler, Ford and Nissan will begin to commercialize FCEVs in the 10,000s per year. BMW/Toyota and GM/Honda will follow with similar sales volumes with effect from 2020 and Volkswagen/AUDI after 2020-2025.

Performance and price of FCEVs

These first commercial FCEVs will have a comparable performance and service life as today's conventional vehicles. They will be able to operate in the same design envelope, e.g. within temperature ranges of commercial cars of -40°C to +85°C. They will have operating ranges of between 500 and 700 km on a full hydrogen tank and can be refuelled in approximately 3 minutes. The targeted worldwide vehicle sales price (excluding taxes) for a medium size sedan in the C/D-class category has been announced to drop from approximately 60k€ in 2015 to 30-35k€ or lower with effect from 2020 and to 21-25k€ by 2030. In order to achieve these cost reductions, mass manufacturing capabilities and a well-established component supplier base will have to be in place. All large manufacturers aiming at mass production have already started to implement the necessary prerequisites. The recent announcements, particularly Toyota's, are fully in line with the analyses provided by the European FCEV powertrain study[22].

Once the results of these announcements materialize, the perception of FCEVs as a clean and practical alternative to today's cars will grow. Consumers will learn that the transition to mature and market ready every day technology is seriously being pursued by the auto manufacturers and that FCEVs will become a real zero-emission alternative to today's petrol-dependent cars. FCEVs will then become accepted as an important complement for battery-powered electric vehicles, each one for its specific market segment.

HRS rollout

As FCEVs have been announced for rollout to initial key markets, the HRS rollout is also in preparation and is supported by the relevant PPPs. Table 1 provides an overview of the present HRS planning for selected regions/countries. E.g. in Germany, the number of HRSs will grow from approximately 16 today to approximately 50 by the end of 2015 and furthermore to 100 by the end of 2017. In Japan the number of stations is targeted to even grow fivefold, from less than 20 stations today to 100 by early 2016. The HRS rollout tries to some extent to anticipate and then to support the communicated and the expected vehicle rollout either in PPPs or in government coordinated initiatives.

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[22] A portfolio of power-trains for Europe: a fact-based analysis, McKinsey & Company, December 2010

EU-policy developments

CO_2 emission regulation

Since 1997 the European Commission has intended to enforce a reduction of CO_2 emissions of passenger cars / light duty vehicles. The threat of regulation was counteracted by the automotive industry (ACEA) in 1999 by a voluntary commitment to reduce new car emissions from 186 g_{CO2}/km in 1995 to 140 g_{CO2}/km in 2008. As industry did not comply with its own commitment, the EC introduced binding legislation instead, forcing the automotive industry in Europe to offer their newly-sold vehicle fleets with average CO_2 emission limits of 130 g_{CO2}/km by 2015 and 95 g_{CO2}/km in 2021. In the transition time, super credits obtained from electric vehicles will also assist to potentially ease achieving these limits. Light commercial vehicles (e.g. delivery vans) are required to remain below 175 g_{CO2}/km by 2017 and 147 g_{CO2}/km by 2020.

The rules will be further tightened when even stricter CO_2-emission limits for new vehicle models are introduced in 2017 and when all registered vehicles with effect from 2018 are expected to be enacted as "*World Harmonized Light Duty Vehicles Test Procedure (WLTP)*[23]" by the European Commission. The WLTP will consider key driving parameters more realistically, such as vehicle configuration, electric management, speed and dynamics in driving cycles (higher top and average speeds, longer cycle duration), powertrain technology, test-cycle tuning, temperature and measurement tolerances. The maximum allowable CO_2 emissions per km have to remain at the 95 g_{CO2}/km value in order to not emit more CO_2. This change, only resulting from a new definition by methodology, will allow or force auto manufacturers to bring more CO_2-free powertrain/fuel combinations to the market than presently foreseen. This move would be clearly a breakthrough for the substitution of highly efficient but increasingly complex and thus costly internal combustion powertrains by electric ones, comprising both FCEVs and BEVs.

Clean Power for Transport

In its endeavour to reduce future fossil energy supply risks[24] and to diminish GHG emissions from transport by 60% from 1990's levels by 2050, the European Commission has developed the Clean Power for Transport (CPT) initiative. The aspiration is to develop a sustainable alternative fuels strategy also including the build-up of an appropriate fuels/energy infrastructure for CNG, LNG, battery charging and hydrogen refuelling and to introduce guidelines and standards for refuelling infrastructure timely and in a synchronized fashion in EU Member States. The Alternative Fuels Infrastructure Directive (AFID)[25], has been adopted 29 September 2014. Article 5 specifies that "***those"*** Member States which decide to include hydrogen refuelling points accessible to the public in their

[23] Development of a World-wide harmonized Light duty Test Cycle (WLTC), UN/ECE/WP.29/GRPE/WLTP-IG, DHC subgroup, Informal document GRPE-68-03, December 2013

[24] The transport sector alone is the largest oil consuming sector at a growing rate of 55%, 94% of transport fuel being provided by oil, 84% of all oil being imported, increasing costs for oil as well as oil purchases representing 2.5% of the European trade balance deficit.

[25] Clean Power for Transport: A European alternative fuels strategy, 2014/xx/EU, Brussels, 29.09.2014 http://ec.europa.eu/transport/themes/urban/cpt/index_en.htm

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national policy framework shall ensure that an appropriate number of such points are available to ensure the circulation of hydrogen powered motor vehicles, including fuel cell vehicles, within networks determined by those Member States, including cross-border links where appropriate, by 31 December 2025 at the latest.

In addition the AFID requires that Member States have to establish national policy frameworks in which they describe their national targets and aims and the supportive actions it takes to develop the market for alternative fuels, including the deployment of the necessary infrastructure. All of this to be developed in close cooperation with local/regional authorities and the involved industries.,

The FCH-JU

Between 2008 and 2015 the European hydrogen and fuel cells public private partnership, better known as the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), supports research, development and demonstration of fuel cell vehicles and hydrogen refuelling infrastructure, co-financed by the European Commission's 7th Framework Program and industry. Large-scale demonstration projects have assisted market preparation already in this program. Fuel cell vehicle and hydrogen refuelling station deployment will be supported more emphatically by the presently initiated FCH 2 JU[26] (now jointly co-financed by the European Commission's Horizon 2020 funding instrument and industry), as well as by EU's Connecting Europe Facility (CEF) Transport program.

Hydrogen infrastructure projects within TEN-T

The European Commission has identified relevant main transport corridors for a better inter-connection of European member states. These corridors are also regarded as a basic skeleton for the initial rollout of cross-border connecting HRSs.

The first Hydrogen Infrastructure for Transport (HIT) project (www.hit-tent.eu) funded by EC's TEN-T program started in 2012. HIT addresses two main questions:

- How can local hydrogen hotspots be turned into local markets with a sufficient critical mass of users and vehicles?
- How can the local HRS be integrated in the context of international corridors?

For this purpose four National Implementation Plans (NIPs) for a hydrogen refuelling infrastructure for France, Sweden, Denmark and the Netherlands have been developed. Furthermore three HRS have been built that will allow long distance trips between urban hydrogen hubs of European importance throughout the TEN-T network: Rotterdam, Aalborg and Frederica.

A Synchronising Implementation Plan (SIP) is being developed, integrating the results of the National Implementation Plans and the lessons learned from other national hydrogen infrastructure initiatives. The SIP could become the blue print for HRS development in those EU Member States which decide to include hydrogen refuelling points in their national policy frameworks.

[26] Fuel Cells and Hydrogen Joint Undertaking 2.0 [http://www.fch-ju.eu/]

The present paper is based on the intermediate results of the SIP and is written by the ECN-LBST-Sweco consortium which is drafting the SIP for the HIT Action, together with the HIT coordinator. The HIT Action will be finalised December 2014. However, HIT has already geared up the level of interaction between private and public stakeholders in the involved countries and beyond.

HIT has also initiated a new TEN-T funded project called HIT-2-Corridors. Within HIT-2-Corridors additional NIPs will be drafted for Finland, Poland and Belgium and a regional plan for Riga (Latvia). Three more HRS will be built along the TEN-T network: Mikkeli (Finland), Stockholm and Gothenburg. HIT-2-Corridors project aims at harmonised deployment of Hydrogen Infrastructure for Transport (HIT) along 2 TEN-T core network corridors (Scandinavian-Mediterranean and North Sea-Baltic) through active interaction with the corridor coordinators. The project includes a large study on “Strategic corridor analyses and plans” focusing on: HRS owner perspective, vehicle customer perspective, and cities and regions perspective.

Conclusions and recommendations

The EC has indicated the need to reduce 1990's CO_2 emissions in the transport sector by 60% by 2050. Even the most advanced ICE technologies will NOT be sufficient to meet this target by far. Consequently, alternative very low CO_2-technologies will need to be applied wherever possible. Basically four of such technologies are available: biofuels, renewable methane, electricity, and hydrogen from renewable energy sources.

FCEVs are an attractive proposition and will become commercially available during the coming years in growing numbers and volumes. In parallel, HRS networks are gradually being established in key markets and the technology is continuously improving and will be fully ready for specific market segments within the next five years. A better coordinated deployment of vehicles and infrastructure in Europe is needed.

Strong policy support and incentives are crucial during the five-year market introduction phase and later during the upscaling towards a serious market share. HRS rollout will already be required in sufficient numbers in the early phases, in order to achieve acceptable area coverage. Due to the initially low number of vehicles, these HRSs will however remain underutilized in the beginning. Therefore, the development of innovative business models and identification and support of the first HRS operators and other local stakeholders to support first fleets, is a precondition. Only this can facilitate initial investments and engage key local industrial and commercial stakeholders. Support mechanisms are also needed for FCEV purchases before the mass production phase is reached from 2020 onwards, which will make FCEVs competitive. This support should be based on both market push and market pull approaches.

Successful instruments in the market introduction phase are: the participation of local/regional and national authorities in public private partnerships (as in the EU), direct funding for FCEVs and HRSs (as in Norway and Japan) and stringent technology-oriented zero-emission vehicle policies (as in California).

The strategic approach for the implementation of FCEVs and HRSs in the four HIT countries considered, i.e. DK, FR, NL and SE, will be reported in the Synchronised Implementation Plan (SIP) providing further detailed facts and recommendations. The report is expected by the end of 2014 and a second article will officially summarise the results of the report in early 2015.

For more information please contact:

Floris Mulder, (HIT coordinator) RWS floris.mulder@rws.nl T: 00 31 88 - 602 2409

Marieke Reijalt (HIT communication) HyER reijalt@hyer.eu T: 00 32 2 - 223 2811

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