National Implementation Plan

Hydrogen Refuelling Infrastructure Belgium

December 2015

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In cooperation with: UCL Université catholique de Louvain

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1. Introduction

1.1 Hydrogen – transport – Europe

Hydrogen in transport

In international energy forecasts, hydrogen is considered as a promising energy carrier. Especially for transport, hydrogen fuelled vehicles are zero-emission vehicles as these vehicles are only emitting water. If hydrogen is produced in a sustainable way (e.g. out of renewable electricity from wind, solar or available as a by-product from chemical industry[1]) the complete well-to-wheel chain is environmental friendly.

Implementation of hydrogen as a fuel for transport requires the implementation of two major new technology-concepts:

- an infrastructure network of hydrogen refuelling stations (HRS)
- fleets of Fuel Cell Electric Vehicles (FCEV)

The last decade, industrial interest in hydrogen technology heavily increased, especially from world-class companies, as well from infrastructure as from automotive OEM's.

Actually worldwide a few hundred hydrogen refuelling stations and about thousand FCEV's are demonstrated and monitored.

Europe – Directives and funding

The European directive on the deployment of alternative fuels infrastructure (2014/94/EU) requires member states to develop national policy frameworks for the market development of alternative fuels and the corresponding needed infrastructure. The alternative fuels are: electricity for electric vehicles, CNG (compressed natural gas), LNG (liquefied natural gas), biofuels, Liquid Petroleum Gas (LPG) and hydrogen. In the directive it's stated that member states have the option to develop hydrogen infrastructure, contrary to the other alternative fuels.

Beside European directives promoting hydrogen in transport, several European funding programmes for demonstration/implementation of new, sustainable technologies are defined. Especially within the programmes 'Fuel Cells & Hydrogen Joint Undertaking (FCH-JU)' and the 'Transnational European Networks for Transport (TEN-T)' hydrogen for transport is an important topic.

[1] No regulations exist to classify by-product hydrogen as an environmental friendly fuel.

1.2 H_2-Mobility initiatives and international results

1.2.1 H_2-Mobility initiative

Based on the industrial experience and triggered by national governments promoting zero-emission transport, there is a need to develop visions/roadmaps on large scale implementation of hydrogen in transport.

Crucial in the development of such a vision is that the development of HRS corresponds as close as possible with the introduction of FCEV's, with a focus on a maximum utilisation of the hydrogen refuelling stations and a smart geographical distribution with the aim to reach economic viable business-cases.

In 2009, Germany was the first country in Europe with the development of an integrated vision on the development of hydrogen refuelling infrastructure and the implementation of FCEV's: 'H_2-Mobility Germany'. An important feature of this H2-Mobility initiative was the direct interaction between the relevant governments and the industry, resulting in a vision with a strong industrial/governmental support and commitment.

This German initiative has been followed by other European countries (Netherlands, United Kingdom, France, Denmark, Sweden,...). Also in California and Japan, visions on the implementation of hydrogen in transport have been developed and implemented.

1.2.2 H_2-mobility results in other countries

<u>Hydrogen Refuelling Stations</u>

Following table shows the results of analyses of HRS-implementation scenario's in other countries for the time-line 2015 – 2030. Also the percentage of existing petrol stations is given.

	Germany	United Kingdom	Nether lands	France	Denmark	California	Japan	South Korea
2015-2020	100	65	20	22[2]	15	68	100	43
2020-2025	400	300	80	355	185	100	1000	168
2025-2030	900	1100	200	600				500

Table 1: Expected roll-out of hydrogen refuelling stations 2015 – 2030

	Germany	United Kingdom	Nether lands	France	Denmark	California	Japan	South Korea
Fuelling stations	14.300	8.600	4.200	12.000	1.975	10.000	34.000	13000
2015-2020	0,7 %	0,8 %	0,5 %	0,2 %	0,8 %	0,7 %	0,3 %	0,3 %
2020-2025	2,8 %	3,5 %	1,9 %	3,0 %	9,4 %	1,0 %	2,9 %	1,3 %
2025-2030	6,2 %	12,8 %	4,8 %	5,0 %				3,8 %

Table 2: Expected share of HRS compared to fossil fuelled fuelling stations

These tables show following average penetration ratio's for HRS.

- 2020 : about 0,5 %
- 2025 : about 2,5 % (exception Denmark with about 10%)
- 2030 : about 5,0 % (exception UK with about 13%)

[2] France: initial focus on 350 bar HRS

HRS initiatives at neighbouring countries Germany, France, The Netherlands, Luxemburg)

In Germany, 6 HRS initiatives are within 90 km of the border of Belgium. In the Netherlands 4 and in France 3. In Luxemburg at the moment no HRS initiatives are foreseen.

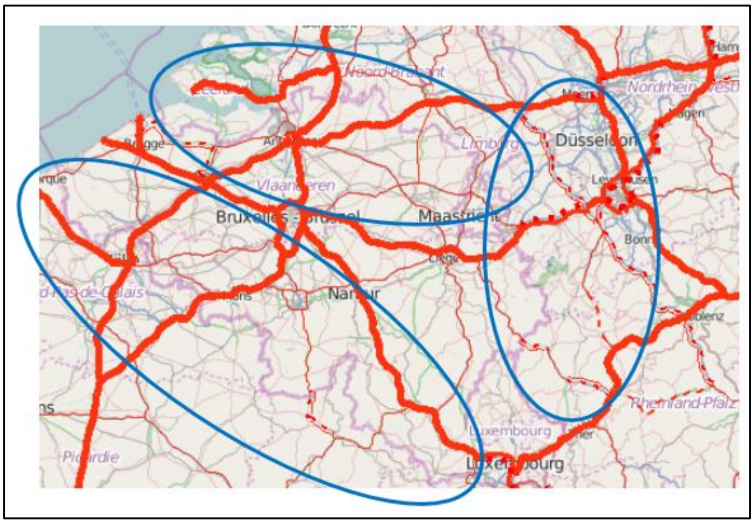


Figure 1: Belgian border area

Fuel Cell Electric Vehicles

Linked to the roll-out of HRS, several estimations in different countries have been made on the amount of hydrogen vehicles to be deployed in the timeframe 2015 – 2030.

	Germany	United Kingdom	Nether lands	France[3]	Denmark	California	Japan	South Korea
2015-2020	10.000	20.000	1.500	1.000	1.000	20.000	15.000	5.000
2020-2025	100.000	300.000	15.000	100.000	100.000		100.000	50.000
2025-2030	1.800.000	1.600.000	150.000	800.000	300.000		500.000	

Table 3: Expected roll-out of FCEV 2015 - 2030

[3] initial focus on range-extender vehicles for captive fleets

1.3 Technology description

1.3.1 HRS concepts

Automotive OEM's aim at fuelling hydrogen in gaseous form at two 'standard' pressures:

- 700 bar: passenger cars
- 350 bar: other vehicles like buses, heavy duty trucks, garbage trucks, forklifts,…

Vehicles are fuelled via a dispenser using a nozzle (Foto 1). Hydrogen nozzles are already standardised for each pressure level.

Foto 1: Hydrogen nozzle

Because of the required pressure, all HRS are equipped with a compressor system combined with a local storage of hydrogen.

Foto 2: Hydrogen Refuelling Station of WaterstofNet on the premises of Colruyt Group

Following ways to deliver or produce hydrogen at the hydrogen refuelling station exist:

- On-site production of hydrogen:
  - by electrolysis: splitting water into hydrogen and oxygen by using electricity
  - by reforming: cracking natural gas/biogas into hydrogen at high temperature
  - by plasma gasification: upcycling the produced syngas from plasma gasification on waste into hydrogen through a watershift reactor
- Trucked in hydrogen
  - Supply hydrogen by trucks, being produced elsewhere
- Connected with possible existing underground hydrogen pipeline network

The time schedule of the vehicles to be fuelled is key in dimensioning the components of the hydrogen refuelling station.

With respect to market development phase, utilisation scenario's, governmental incentives etc., other capacity configurations and technological options are possible. Also, power-to-gas/power-to-power concepts could play an important role for instance, to improve the flexibility of the electricity grid.

1.3.2 Fuel Cell Electric Vehicles (FCEV's)

Fuel cell electric vehicles are equipped with a fuel cell, generating electricity by combining oxygen and hydrogen in a chemical reaction. The electricity is used for propulsion of the electromotor and to charge a small battery. When pure hydrogen is used, the only products are heat and water. The production of hydrogen can be sustainable if produced from renewable energy like wind or solar.

Advantages of fuel cell electric vehicles:
- zero-emission from tank-to-wheel and almost 100% from well-to-wheel if hydrogen is produced from renewable energy or in case by product hydrogen is used;
- higher efficiency than combustion engines;
- Fast refuelling: passenger car within 3-5 minutes; bus within 12 minutes
- Large driving range compared to battery electric vehicles: passenger cars about 500 – 600 km, buses about 350 – 400 km

Issues to be solved:
- Cost of fuel cells;
- Cost of producing renewable hydrogen;
- Lack of refuelling infrastructure;
- Public acceptance of hydrogen

FCEV's can be categorised into vehicles into light- and heavy duty:

<u>Light duty</u>:

- Passenger OEM-cars on 700 bar gaseous hydrogen, fuel cell dominated, small battery;
- Light duty vehicles/light commercial vehicles on 350 bar gaseous hydrogen, hybrid: fuel cell and battery.

Passenger cars

Regarding passenger cars from OEM's it is only since 2013 that fuel cell electric vehicles are 'commercially' available: Hyundai produced the first series of 1.000 Hyundai ix35.
As the roll out of FCEV will be completely defined by the availability of cars, the introduction of FCEV's is crucial in the roll-out scenario's, as Figure 2 shows.

This means that up to the end of 2017, only a few thousand FCEV's will be available on the market and in 2020 several tens of thousands of cars will be available on the world-wide market.

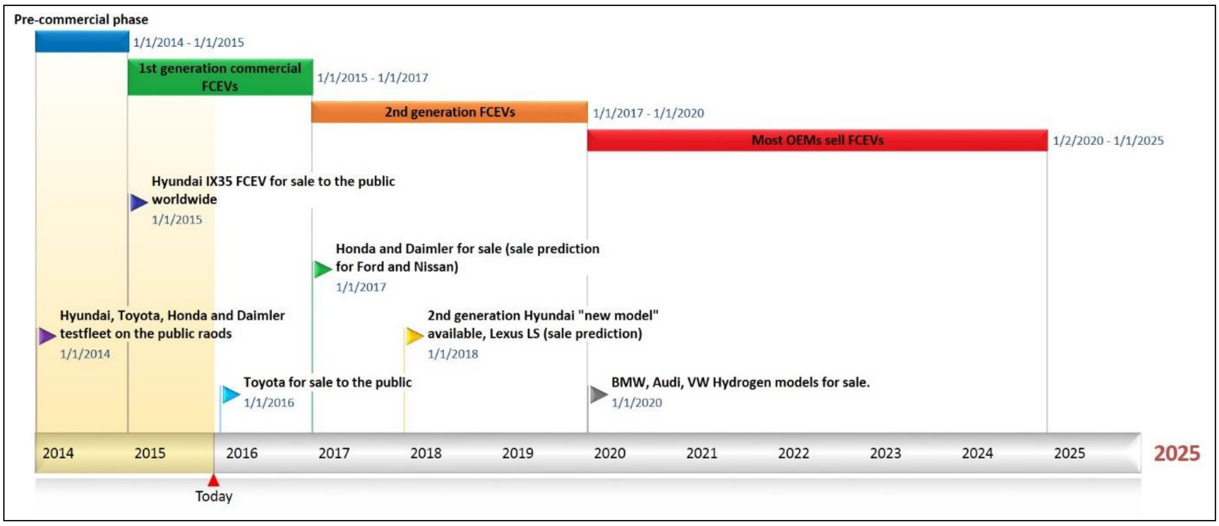


Figure 2: Foreseen introduction of passenger FCEV's

Foto 3: Hyundai ix 35

Foto 4: Toyota Mirai

Foto 5: Mercedes Benz F-Cell

Foto 6: Honda FCV concept car

Foto 7: Nissan Terra FCEV concept car

Range-extender cars

Recently, cars with a hybrid concept, based on a small fuel cell and a relatively large battery, have been put into demonstration projects. Especially for captive fleets for companies focussing on delivery services (e.g. postal services,…) these type of hydrogen fuelled hybrid vehicles can be interesting because with the fuel cell, typical logistical operations can become feasible for 2 or 3 shifts. The fuel cell with hydrogen storage simply adds more energy to the vehicle and is able to refuel in a few minutes.
The coming next years, a few hundreds of these vehicles will be demonstrated in Europe.

Foto 8: Renault Kangoo ZE-H2

<u>Heavy duty</u>

- Buses for public transport on 350 bar gaseous hydrogen, hybrid: fuel cell and battery
- Trucks, such as garbage trucks, on 350 bar gaseous hydrogen: hybrid: fuel cell and battery

Buses

Foto 9: Fuel Cell Bus manufactured by Van Hool operated by Flemish bus operator De Lijn

Europe is leading in demonstrations of fuel cell buses on hydrogen, initially focussing on 'standard' buses of 12 meter, but also demonstrations with articulated buses on hydrogen have been initiated now. As governments are more and more focussing on improving air quality, he interest for zero-emission public transport increases.
Implementation of hydrogen in public transport has the following advantages:

- public transport is in most cases a combination of government and industry;
- Buses are a captive fleet with defined/fixed routes/drivers;
- The capacity and utilisation of a HRS can be matched directly to the hydrogen consumption of the buses.

Up to now, most hydrogen bus demonstrations in Europe are equipped with 5 buses. Aberdeen has the largest bus fleet in operation (10 buses, 2 bus operators with each 5 buses). Following years Europe is aiming for bus demonstrations with 20 – 30 buses per site.

In 2014, a coalition of European cities and bus operators has expressed their ambition to operate about 400 hydrogen buses. Five bus OEM’s (Van Hool, Mercedes, VDL, Solaris and MAN) have indicated their target to sell hundreds of hydrogen buses in 2020.

Trucks

There is an increasing interest in hydrogen as a fuel for trucks as it is an added value for trucks to be ‘zero-emission in combination with zero-noise’. Meeting these requirements trucks might be allowed to enter city centres during the evening and/or night.
Examples of interesting truck-applications are garbage trucks and city delivery trucks: developments and demonstrations of these hydrogen fuelled vehicles are just starting now in Europe.

Foto 10: Garbage truck on hydrogen

2. Objectives H_2-Mobility Belgium

2.1 Hydrogen Infrastructure in Transport 2 (HIT-2)

Within this HIT-2 project a vision for the implementation of hydrogen in transport in Belgium has been developed, called “H2-Mobility Belgium”, the National Implementation Plan (NIP) for Belgium (NIP-Belgium).

The objectives of H_2-Mobilty Belgium are:

- to develop a National Implementation Plan (NIP) for the implementation of a hydrogen refuelling infrastructure in Belgium for the timeline 2015 – 2030, focussing on the TEN-T corridors and connection to the NIP’s in the neighbouring countries
- to prepare the Belgian market for the introduction of fuel cell electric vehicles, focussing on passenger cars and buses

From a TEN-T perspective it is important notifying that 3 major TEN-T-corridors are crossing Belgium, North Sea-Baltic corridor, Rhine-Alpine corridor and the North Sea-Mediterranean corridor.

Figure 4: North Sea-Baltic corridor

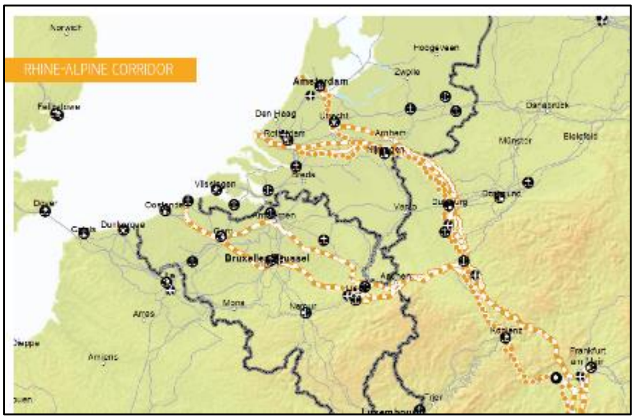


Figure 5: Rhine-Alpine corridor

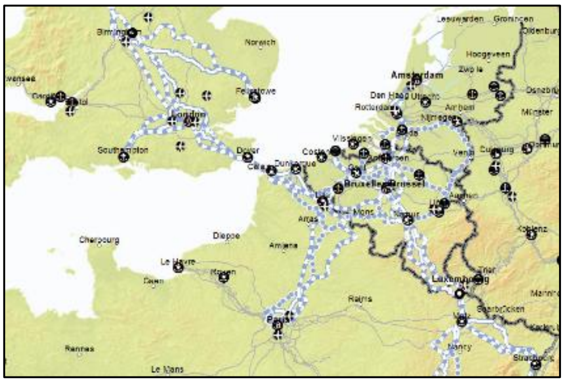


Figure 3: North Sea-Mediterranean corridor

2.2 Status in Belgium

2.2.1 Hydrogen in Belgium

Though Belgium has not the reputation of being a frontrunner in hydrogen, it has unique strong points on hydrogen:

- the centre of the largest underground pipeline transport network of hydrogen[4] is situated in Antwerp: the hydrogen network is owned and exploited by Air Liquide
- the port of Antwerp is one of Europe's biggest areas for the production of hydrogen (coming from natural gas as well as being a by-product from chemical industry).
- Belgium is home for a rather overarching industrial value chain on hydrogen with companies as Hydrogenics, Umicore, Solvay, Agfa Gevaert, Borit, Van Hool, Toyota Motor Europe, Hyundai, Air Liquide, Colruyt Group,…

Recently following demonstrations projects were realised:

- 1 MW fuel cell plant on by-product hydrogen at Solvay;
- 5 hydrogen buses (Van Hool) using by-product hydrogen in a dedicated HRS in Antwerp (HighVLOcity, FCH-JU);
- 11 forklifts on hydrogen at Colruyt;
- 1 HRS at Colruyt site, owned by WaterstofNet, using renewable electricity for the production of hydrogen, fuelling fork lifts on hydrogen;
- Demonstration of the hydrogen refuelling station at the Colruyt site as part of a smart grid application (Don Quichote, funded by Joint Undertaking Fuel Cells & Hydrogen).
- At the moment 4 Hyundai iX35 on hydrogen are driving in Belgium (Colruyt, WaterstofNet and 2 for the FCH JU);
- The first public HRS near Brussels will be put into operation in 2016 by Air Liquide (SWARM-project, FCH-JU) on the Toyota Motor Europe site;
- Recently, the 3Emotion project (funded by JU-FCH) has been approved and foresees 3 additional buses , built by Van Hool, for Antwerp.

[4] Due to contamination, hydrogen from industrial byproduct is not directly usable for fuel cells.

2.2.2 Petrol stations and vehicle fleet in Belgium

Belgium (30.500 km², 11 million in habitants) is one of the most dense populated countries in the world (average about 360 habitants/km²) and has relatively a large amount of cars and petrol stations.

Characteristics for Belgium:

- Passenger cars:
  - 5,5 million passenger cars (2014, average: 1 car for two inhabitants);
  - Europe's highest share of diesel cars : 62% diesel, 38% is gasoline (2013);
  - Non-homogenous distribution vehicles across the regions: Flanders 55%, Wallonia 29%, Brussels 16%;
  - High share of cars for companies by leasing companies;
  - Very low penetration of zero-emission battery vehicles (< 0,001%).

- Fuel infrastructure
  - 3.158 petrol stations
    dense network compared with 4.180 stations in Netherlands (41.526 km², 16 million inhabitants), and with 14.678 stations in Germany (357.000 km², 80 million inhabitants);
  - All refuelling stations on the highway are granted by auctions.

- Buses/public transport
  - Public transport is completely public owned with a juridical entity for each of the three regions (Flanders, Wallonia, Brussels)
  - Flanders:
    - about 2000 buses
    - about 55 premises
    - operated by bus operator De Lijn
  - Brussels:
    - about 700 buses
    - about 3 premises
    - operated by bus operator MIVB/STIB
  - Wallonia:
    - about 600 buses
    - about 46 premises
    - operated by bus operator TEC

2.2.3 Governmental framework in Belgium

Regarding implementation/promoting/supporting of zero-emission transport on hydrogen, it is important to notify that Belgium is a federal state (Belgium), composed of communities (Flanders, French-speaking, German-speaking) and regions (Flanders, Wallonia, Brussels), resulting in 6 governments.

With respect to promoting sustainable transport it is key to know that issues regarding fiscal climate are partly defined by the federal state and partly by regional authorities: this mix of governmental authorities makes a clear uniform support scheme for sustainable transport on the overall Belgian-level complicated. Therefore a structural cooperation between federal and regional authorities is necessary to realise targets on sustainable transport.

2.2.4 Regulations, safety, inspections

In Belgium one non-public HRS at Colruyt in Halle has been put into operation in 2012 and the first public HRS at Toyota in Zaventem will be put into operation in 2016. Therefore knowledge and experience of permitting, regulations, safety measures and inspections is very limited. It is recommended to cooperate with neighbouring countries in order to build up knowledge and experiences in an efficient way. Issues that have to be discussed are procedures concerning exploitation of HRS, annual inspection of FCEV's, parking of cars in parking buildings/garages, guidelines for first responders.

2.3 Targets Hydrogen refuelling stations (HRS) and fuel cell electric vehicles (FCEV)

2.3.1 Targets for Hydrogen Refuelling Stations

The starting point for the number of HRS in Belgium is that these will be in line with the targets in neighbouring countries. Therefore a target of 25 HRS in Belgium in 2020 is formulated: 20 HRS in Flanders and 5 HRS in Wallonia. First HRS developments are foreseen in the major cities in Belgium and in the neighbourhood of the TEN-T network.

After 2020, it is expected that almost all OEM's will have FCEV's on the market and a real market introduction will start. Between 2020 and 2025, 45 additional stations are planned. After 2025, the network could grow to 150 HRS in 2030.

Calculating with about 3.200 petrol stations in Belgium, the amount of HRS refers to 0,8% (2020) via 2,3% (2025) to 4,7% (2030). This is completely in line with the targets in other H_2-Mobility countries.

Period	Belgium	Flanders	Brussels	Wallonia
2015-2020	25	20	0	5
2020-2025	75	50	5	20
2025-2030	150	100	10	40

Table 4: Roll-out of HRS in Belgium

Regarding HRS, the average investment cost of a HRS is estimated at 2 million euro (2020)[5], resulting in an overall investment cost of about 50 million euro towards 2020. With 1,2 million euro average CAPEX in 2025, additional needed CAPEX will be about 65 million euro between 2020-2025. With an average CAPEX of HRS of 750 keuro in 2030, the additional cost for 2030 will therefore be about 55 million euro.

This results in overall CAPEX for HRS up to 2030 of about 170 million euro.

The network development has been projected in three figures. The colors represent the amount of HRS that will be developed in or around a particular city-area.

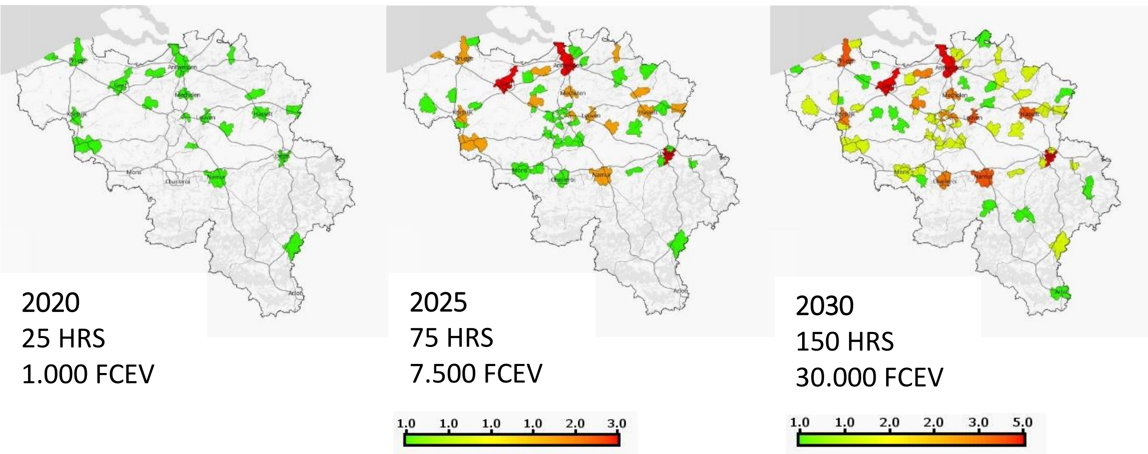


Figure 6: A visual representation of a possible network development in Belgium

[5] Investments, but also operational costs are much depending on the size, capacity and the production technology for hydrogen.

2.3.2 Targets for Fuel Cell Electric Vehicles

The availability of FCEV's is one of the key criteria within the development of a HRS-network.

Based upon announcements of market introduction an estimation on the number of vehicles on hydrogen till 2030 has been made.

For 2020 it resulted in about 1.000 FCEV's in Belgium which is almost 0,02% of the total vehicle fleet. From our perspective, this characterizes the phase in which hydrogen mobility in Belgium is present. After 2020, during the early market introduction (2020-2025), the amount of FCEV's will grow to possibly 7.500 FCEV's. This is almost 0,15% of the market. Finally, between 2025-2030, a ramp up could emerge which results in 30.000 FCEV (0,55% market penetration).

Period	FCEV	FCEV/HRS
2015-2020	1.000 (0,02%	40
2020-2025	7.500 (0,15%)	100
2025-2030	30.000 (0,55%)	200

Table 5: Roll-out of FCEV in Belgium

For buses, the target is 50 buses in 2020, 250 in 2025 and 500 in 2030.

The cost of a passenger FCEV up to 2020 is on average about 60 keuro.

Finally, assuming that one car uses 250 kg/year (25.000 km/year and efficiency 1kg/100km) and a bus 8.000 kg/year (80.000 km/year and efficiency 10kg/100km), the amount of hydrogen and electricity (to produce 'green' hydrogen) needed for mobility has been calculated.

Period	FCEV	Buses	Hydrogen demand (ton/year)	Electricity (TWh)*
2015-2020	1.000	50	650	0,04
2020-2025	7.500	250	3.875	0,22
2025-2030	30.000	500	11.500	0,67

Table 6: Targets HRS, FCEV and buses, hydrogen demand and renewable electricity needed in Belgium (electricity produced by wind and solar in Belgium in 2013 was 4,6 TWh)*

2.3.3 Ecological impact

With Euro 6 as a reference, Table 1 shows the avoided emissions and the external costs for FCEV[6].

Period	NO_x (kg)	PM (kg)	CO_2 (ton)	Million €
2015-2020	2.900	180	5.000	€0.3
2020-2025	49.000	3.060	85.000	€5.1
2025-2030	210.000	13.125	364.000	€21.9

Table 7: Avoided emissions and calculated reduced external environmental costs for FCEV

Based upon our assumptions, the benefits brought by a vehicle fleet of 30.000 being 0,5% of the Belgian passenger vehicle market and displacing Euro6 diesel vehicles, could save more than €27 million societal costs by 2030. If we look at the growth scenario of FCEV's until 2050, being 25% of the vehicle fleet, based upon our assumptions, the societal cost savings in terms of CO2, PM, NOx and noise could reach €3 milliard.

[6] Buses were not taken into account within this calculation

2.4 Overview of possible incentives linked to governmental levels

Different member states in the EU use al kind of incentives to promote the development of hydrogen in mobility. Incentives are needed to create (investor) confidence in the marketplace. A comprehensive plan with all kind of incentives that fit to each development phase will be necessary.
Possible incentives are listed in Table 8 .

National/regional incentives to promote HRS and FCEV	Federal	Regional	Provincial	Local
General				
National H_2 coordinator facilitating the implementation	√	√		
Align hydrogen in mobility with other plans like storage of electricity, renewable energy, air quality policy etc.	√	√		
Incentives for production of 'green' hydrogen		√		
Investment support for industrial scale demonstration projects		√		
HRS incentives				
Excise duty exemption for hydrogen (fit to market development phase)	√			
Public procurements/auctions for refuelling stations near highways (extra requirements for alternative fuels and/or extension contracts if clean fuels are offered)		√	√	√
Fossil fuels added CO_2 and energy tax	√			
Introduce certificate system as part of Renewable Energy Directive (i.e. Bioticket-system in The Netherlands) (Double/multiple counting for hydrogen related to Renewable Energy Directive)[7]	√	√		
Governmental subsidies in station CAPEX and OPEX:				
Capital expense grants for HRS (linked to cost or capacity)		√	√	
Operation expense grants (linked to cost, capacity or throughput)		√	√	
Market assurance grants (linked to utilization)		√	√	
Possibly for first mover benefits: - Geographical buffer for early investors - Priority status - Multi-station grants		√	√	
Tax benefit for investment and production		√		
Tax benefit for accelerated and bonus depreciation		√		
Tax benefit for property and other exemptions		√		
Permitting support by offering clear procedure/legislation		√		√
Promote 'living labs' (HRS coupled to local and regional vehicles/fleets)		√	√	√
Introduce zero emission target for governmental fleets (buses, waste companies etc). Fleets connected to HRS are important early clients		√		
Organise workshops/seminars (supply meets demand)	√	√	√	√

[7] For more information on multiple counting of alternative fuels see http://www.biofuelstp.eu/biofuels-legislation.html

FCEV incentives				
Public procurements with zero emission targets	√	√	√	√
Negative incentives for fossil fuels like diesel, natural gas and petrol	√	√		
Reduced registration tax depending on tailpipe CO_2		√		
Purchase support depending on tailpipe CO_2		√		
Reduced tax on car ownership		√		
Reduced tax on private usage		√		
Tax deductions for environmentally friendly investments	√	√		
Specific incentives for specified fleets (taxi's, garbage trucks, logistics etc)		√	√	
Free public parking				√
Road fee exemption				√
Driving in bus lanes				√
Carpool lane driving			√	√
Taxation of private use of company car	√	√		
Traffic ban during certain time periods				√
Low Emission Zones				√
Subsidy on buying vehicle			√	√
Reduced congestion charges		√		

Table 8: List of possible incentives related to the governmental authority

2.5 Market phases and challenges

In the roll-out of hydrogen refuelling stations and the FCEV's following market phases can be distinguished, every market phase is characterised by specific challenges, objectives, results and lead investors (table 2.6):

1. market preparation (2015-2020),
2. early market introduction (2020-2025), and
3. full market introduction (2025-2030).

	Target	Core challenge	Objectives	Result of phase	Lead investors
market preparation (2015-2020)	HRS: 25 FCEV: 1.000 Buses: 50	Overcome uncertainty	Build HRS network to sufficient coverage Enable sale or leasing of early commercial vehicles Monitor reliability of network	Enough demand and/or projected demand sufficient early infrastructure coverage	Government Strategic investors
early market introduction (2020-2025)	HRS:75 FCEV:7.500 Buses: 150	Maintain investment interest	Upgrade existing and build new stations based upon FCEV projections Monitor reliability of network	Critically risk and uncertainty have been removed Better understanding on FCEV adoption, station deployment timelines and capability	Government Strategic & equity investors
full market introduction (2025-2030)	HRS:150 FCEV:30.000 Buses: 500	Enabling transition to and competitive private market	Build new stations Downgrade governmental support	Market takes over development of network	Equity investors Some government support

Table 9: Core challenges, objectives and results for each market phase

Costs and revenues determine the business case for a hydrogen refuelling station. Costs are composed of capital expenditures (CAPEX) and operational expenditures (OPEX). Revenues are determined by the number of FCEV's to be fuelled.

These costs and revenues are determining the utilization of the HRS, being a very important parameter in the financial viability of a HRS.

In general, a HRS operator faces the following main challenges:

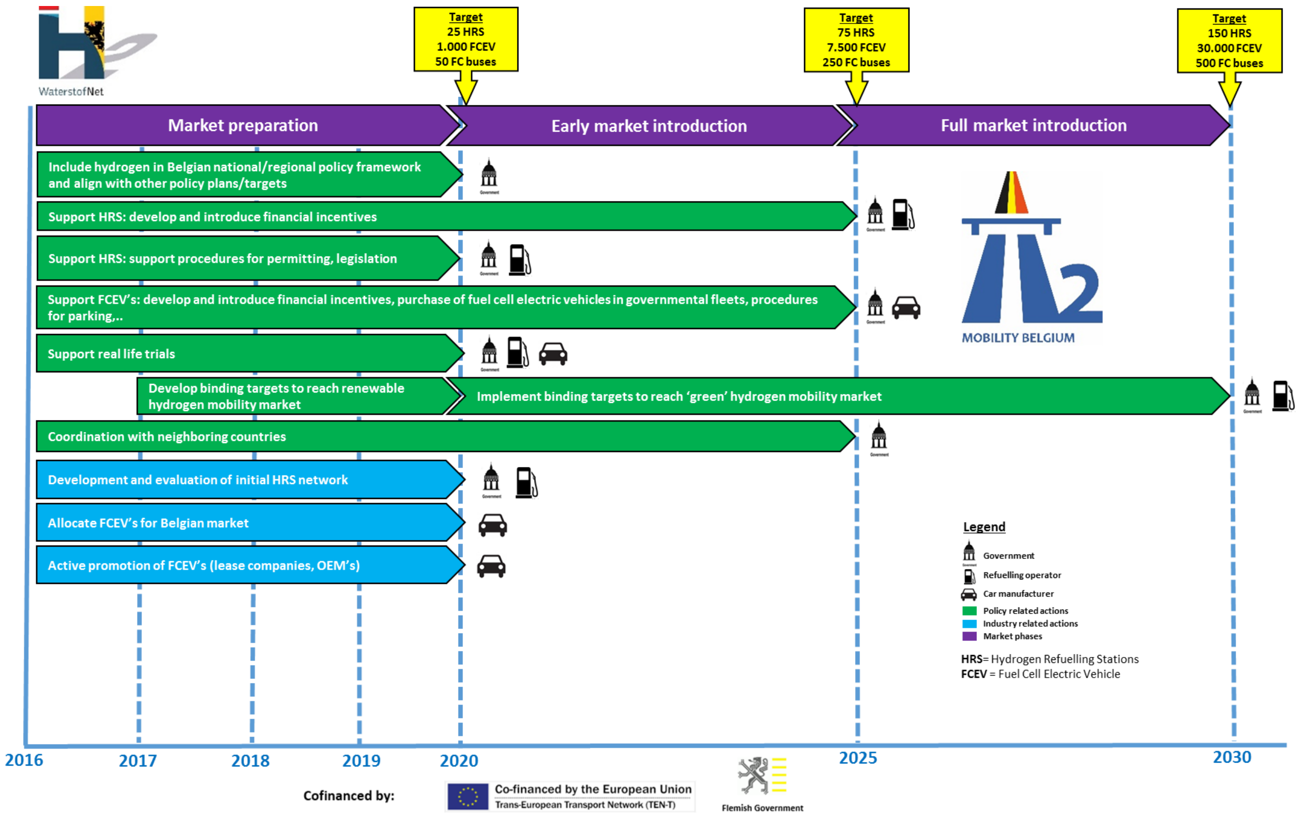
1. High initial investments needs and operational costs
2. Initial underutilization
3. FCEV ramp-up risk

In order to overcome these challenges a close cooperation between companies concerning HRS and FCEV's and the government is needed, with a focus on:

- creating a first-mover advantage: only financial support for early movers;
- help to mitigate the FCEV ramp-up risk by requiring a minimum share of zero-emission vehicles in large fleets and other incentives to support market pick-up;
- increasing the strategic value of the HRS rollout: this is about regulations which can make the need for the HRS network more urgent.

3. Action plan

Following action points have been defined to start the implementation of the market for hydrogen refueling infrastructure and fuel cell electric vehicles in Belgium[8]. Also the most important stakeholders are mentioned. A more detailed description has also been provided in this section.



[8] It was not part of this study to calculate the costs for implementing these actions.

1. Include hydrogen refueling stations in the Belgian national/regional policy framework

In the context of directive 2014/94/EU on the deployment of alternative fuels infrastructure, new infrastructure has to be developed in Europe for electricity (for battery electric vehicles), natural gas (Compressed and Liquefied Natural Gas) and where appropriate hydrogen. Based upon the conclusions in this report and in particular the economic and environmental opportunities, it is recommended to positively decide on the roll-out of hydrogen as fuel for transport in the Belgian national and regional policy framework.

2. Take a facilitating role to create confidence in the market for hydrogen mobility

It is recommend that the Federal and Regional governments will take a facilitating role in developing the market for hydrogen mobility with the objective to create confidence for all stakeholders concerned. Within this facilitating role, it is recommended to:

- Organize a **synchronized ramp-up** of hydrogen stations and vehicle deployment together with a public/private consortium compromising key stakeholders. Robust commitment from public stakeholders is very important in gaining confidence in the market.
- Develop an **investment plan** (with risk sharing mechanisms) with clear commitments from industry/investors, roles and responsibilities, concrete roll-out strategy with cross border linkages, risk minimizing incentives (secure funding and assurance for early movers in this market) and long term commitments to ensure enough confidence for investors to enter the market.
- Organize an **independent hydrogen coordination and implementation team** which monitors the market developments (market barriers, opportunities, consumer awareness,…), conduct local HRS&FCEV deployment plans, performs infrastructure monitoring, organise information events, communication, conduct annual vehicle surveys, yearly update government strategic plan with new activities, finding partners for specific challenges, has contact with stakeholders, looks for opportunities within European programs and will recommend the government on how to align incentives with the challenges faced by private companies and other stakeholders. From the governments, a legal expert can be delivered to help accelerate legislation procedures.
- Stimulate **innovative demonstration projects** within existing governmental programs.

3. Align and stimulate developments in hydrogen mobility with other policy plans/targets

Hydrogen not only contributes to climate and air quality policy but also to other national challenges and opportunities like grid balancing, storage of surplus renewable electricity, greening the chemical industry etc. Therefore, hydrogen could be part of a bigger strategy and this can further be surrounded with incentives to promote the use of hydrogen in other sectors.

4. **Develop and introduce incentives to stimulate fuel cell electric vehicle purchase and driving, also for niche fleets.**

One of the main issues for a hydrogen refueling station operator is the underutilization (long and short period) of the infrastructure. A set of recommendations are important to overcome this situation and need further discussion with the government and other stakeholders:

- **Grants** for FCEV linked to the additional costs of these vehicles and the impact on sustainability
- **Exemptions for taxes** regarding the use of the car
- **Use own governmental fleets to help early movers in the market*:*** operators of HRS face high risks on operational losses in the early years when exploiting a HRS, known as the early mover disadvantage. This is because of the low number of vehicles that will be on the market. To communicate good examples and to help early mover station operators, governmental anchor fleets could be of importance. The government has the possibility to contribute to the development by using their own fleets like buses, garbage trucks and utility vehicles to reach zero emission. It is recommended to investigate which fleets and locations could be developed to zero emission fleets to encourage the market for zero emission mobility.

- **Stimulate companies with big (niche) fleets to reach zero emission:** the government can take a leading role to develop a Letter of Intent with Belgian companies to implement zero emission vehicles in their fleets or help to mitigate the FCEV ramp-up risk by regulation requiring a minimum share of zero-emission vehicles in large fleets and other incentives to support market pick-up.

5. **Develop and introduce incentives to stimulate investment and operation of hydrogen refueling stations**

A set of recommendations are important in this particular situation especially for the regional governments and need further discussion with the government:

- **Create a first-mover advantage:** only financial support for early movers.
- **Encourage swift action by setting a limited time period during which the first-mover advantage is available:** this can be done with a tender for a concession forcing industry stakeholders to align and submit a proposal.
- **Help push down financing costs:** like issuing guarantees for public bank loans or make public bank products available.
- **Stimulate combined hydrogen refueling stations*:*** Pay specific attention to the development of combined hydrogen refueling stations which serve as a station for passenger vehicles and large fleets (like buses and garbage vehicles). It is recommended to start an initial study with the focus on these kind of fleets which can also serve as public refueling stations.

- **Create incentives for higher cost of hydrogen from renewable electricity and waste*:*** e.g. this can be done by the introduction of a bioticket system like in The Netherlands, Germany etc. The bioticket system has been developed to reach the targets within the EU Renewables Directive (RED) which seeks to achieve a 10% share of renewables of the final energy consumption in transport by 2020. Companies which deliver transport fuels to the market, have the possibility to sell biotickets to other companies which cannot or want to blend biofuels. In The Netherlands, green gas (subsidy free) injected into the gas grid, can generate extra earnings when this green gas is being sold via CNG refuelling stations. In case of green gas being produced from waste streams, the earnings go up by multiple crediting. The bioticket system and multiple crediting of these fuels can stimulate the market (if the earnings also reach the producer). Hydrogen from renewable sources have a big potential to contribute to the objectives of the RED.

6. Implement binding targets to reach 'green' hydrogen mobility market

At the moment, most of the produced hydrogen in Belgium originates from steam methane reforming or from hydrogen as a by-product. In case natural gas is the main energy source, it doesn't meet the requirements to reach a low carbon mobility system. Users of FCEV's and the community expect that the market will decrease the carbon footprint for the production and use of hydrogen and reach 100% renewable hydrogen in the future. Low carbon solutions are relatively expensive because of their short development history and mismatch within our energy system based on fossil energy. To start with the development of the hydrogen mobility market in Belgium, we expect the use of non-renewable based hydrogen (e.g. from natural gas, coal, oil, nuclear energy) will be accepted only if there is a clear ambition to reach a 'green' hydrogen market in Belgium. We recommend to:

- Decide on introducing binding targets for the sale of 'green' hydrogen in Belgium and start discussions with stakeholders.

- Develop and invest in 2 innovative projects in metropolitan areas (for bus and passenger vehicles) to demonstrate a 100% renewable hydrogen refueling station possibly in combination with storage and grid balancing services.

7. Cooperate with the neighboring Benelux-countries

From conversations with industry (car OEM's as well as hydrogen infrastructure suppliers), governments and the European FCH-JU, it seems to be an added value to coordinate the activities of Belgium with Luxemburg and The Netherlands to maximize efficiency of investments and European support.

8. Develop practical guidelines for hydrogen refueling stations and organize workshops

There is some experience with permitting procedures for hydrogen refueling stations in Belgium. But, to reach the ambitions for the roll-out of infrastructure, it's important to have clear guidelines (regulations, requirements, criteria and conditions) for the installation of safe hydrogen refueling stations. It is recommended to start discussions with regions and provinces to develop a comprehensive set of guidelines for hydrogen refueling stations. The Dutch 'Publicatiereeks Gevaarlijke Stoffen nr. 35' can be used as an example. Later, workshops can help to communicate with governmental and industrial stakeholders to share knowledge in this field.

9. Start discussions around optimizing regulations, inspections, permitting etc.

Following in-person meetings and conversations with different stakeholders some recommendations can be made regarding the introduction of FCEVs in Belgium. These recommendations are primarily for the regional governments.

- Develop and execute a comprehensive study with relevant stakeholders in which gaps and obstacles are being analysed within the existing Belgian legal framework regarding cars and refuelling stations;
- Include a separate 'waterstof' chapter within VlaRem. This has also been done for natural gas and LPG. From this rubric, references can be used to link to the applicable norms.
- Reconsider the current inspection procedures and tests for hydrogen and align with norms, experiences and advices from component manufacturers.
- Organize knowledge exchange workshops around standardization of approval processes for hydrogen refuelling stations in Belgium to upgrade the knowledge level. Target groups are local municipalities, provinces, fire departments and other relevant stakeholders
- Drafting a common chapter lay-out for safety studies and permitting procedures (It's important to know where the differences are in comparison to regular fuels)
- Recognition of vehicles and their fuel or powertrain is very important for first responders. At the moment an ISO proposal is proposed to the ISO commission to imply a symbol (with color-coding) to be able to recognise the different drivetrains and fuels that are being used for transport. This should be implemented top down.
- Close cooperation with and publications of results from projects like "HyFive", "HyResponse" and possible learnings from the implementation of CNG, would enhance the pick-up of hydrogen as a fuel.
- Also for dealers and inspection authorities some guidelines should be prepared in close cooperation with authorities and the OEMs to have a complete insight in possible actions to be taken, to be able to work on hydrogen vehicles in workshops or for storing them in garages.