PROJECT FINAL REPORT

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Cities speeding up the integration of hydrogen buses in public fleets

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Content

List of abbreviations

3Emotion - **E**nvironmentally friendly **E**fficient **E**lectric **Motion**

ACC - Aberdeen City Council

AIP - Annual Implementation Plan

BEV – Battery Electric Vehicles

CHIC - Clean Hydrogen In Cities

CO2 - Carbon dioxide

CO2e - CO2 equivalent, considering emission of carbon dioxide (CO2), methane (CO4) and nitrous oxide (N2O)

DL – Vlaamse Vervoersmaatschappij DeLijn

DoW - Description of Work

DRB - Diesel Reference Bus

EURO V - Emission standards for heavy-duty diesel engines (trucks and buses), in effect for new type approvals since 1 October 2008

EURO VI - Emission standards for heavy-duty diesel engines, in effect for new type approvals since 31 December 2012

FC - Fuel Cell

FCB - Fuel Cell Bus

FCH JU - Fuel Cells and Hydrogen Joint Undertaking

GHG - Greenhouse Gas(es)

High V.LO-City - Cities Speeding up the Integration of Hydrogen Buses in Public Fleets

HPU - Hydrogen Production Unit

HRS - Hydrogen Refuelling Station

HRU - Hydrogen Refuelling Unit

JIVE - Joint Initiative for hydrogen Vehicles across Europe

KPI - Key Performance Indicator

LCA - Life-cycle assessment

OEM - Original Equipment Manufacturer

OPEX - Operational Expenditure

NCV - Net Calorific Value (also called “lower heating value”)

NOx - Nitrogen Oxides, emitted in the form of Nitric Oxide (NO) and Nitrogen Dioxide (NO2)

PM - Particulate Matter

PP – PitPoint

PTO – Public Transport Operator

RT – Riviera Transporti

SORT - Standardised On-Road Test cycle

TCO - Total cost of ownership

WP - Work Package

Disclaimer and acknowledgement

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Executive summary

The High V.LO-City project ran from January 2012 until December 2019 and aimed to accelerate the integration of a new generation of FCH buses (14 FC buses were operated in Scotland (UK), Liguria (IT), Flanders (BE) and Groningen (NL)) in the public transport system and operate them in fleets and in the same time demonstrating the technical and operational quality. It contributed in showing their value in creating a clean and highly attractive public transport service (/system) and facilitated the modular shift that local transport policies were and still are envisioning. By effectively linking previous (CHIC) and future demonstration sites (3Emotion & JIVE), the project seeked to further broaden and consolidate a network of successful FCH bus operators that is able to widen the dissemination of FCH bus operations in Europe.

Since 2002 several EU supported fuel cell bus programmes have successfully demonstrated the technical feasibility of operating fuel cell buses and refuelling hydrogen in public transport operations. Bus manufacturers consider the fuel cell hybrid (FCH) electric bus as the most promising technology to substitute the diesel and or hybrid buses in the coming years, as FCH technology will contribute significantly to reduce local transport emissions and to simplify operations. In order to facilitate a smooth integration of FCH buses, specific requirements with regards to maintenance, environmental and financial sound operations of public transport fleets needed to be addressed, including:

- Increase energy efficiency of buses;
- Reduce the total cost of ownership;
- Increase the life time of the fuel cells;
- Reduce life cycle costs and more specifically the cost of hydrogen;
- Define concrete economic early markets;

These, a the time, latest generation (3rd) of FCH buses in the High V.LO-City project reaches efficiency levels, that went further than those tested in previous fuel cell bus projects. In addition, experiences from past projects point to the importance of addressing public transport needs for more flexibility and for modular hydrogen capacity build- up, that have not been implemented so far. Last but not least EU regulations, as the EU Directive on the promotion of clean and energy efficient road-transport vehicles (COM 2009/33) require public authorities to include life cycle costs including energy consumption and CO2 emissions into their procurement decisions.

During the projects' lifetime, all 14 buses and 3 planned HRSs (and 1 additional HRS) were delivered and operated in the 4 European regions, operating and fuelling these hydrogen electric hybrid buses in different parts of Europe under deviant geographical-, climate- and operational conditions.

Important on the topic of the HRSs included in the project was the aim for a reduction of costs of the hydrogen supply in the local sites:
o Liguria: linking with renewable hydrogen sources
o Antwerp: using by-product hydrogen from industry
o Aberdeen: making use of an existing hydrogen production and distribution mechanisms and eventually Scotland's extensive wind energy resources
o Groningen: by using H2 taken by a pipeline as a by-product from chlorine production

The project realised more than **1 Million kms** driven throughout the project, consuming between **9 - 13 kgs/100km**. Fuelling the buses between **10 - 12 mins** at the projects' HRSs with an average availability of **96,8%.** These numbers combined mean **> 1000T of CO2** emissions were **saved** by the project.

Beside these physical demonstrations, the project, with help of a vast communication- and dissemination plan as well as the creation of a knowledge portal/ centre of excellence, also enlarged the reach out to and the understanding of the local, national and international general public, policy makers and other public transport operators.

Project context and objectives

Europe, the European Union (EU) and its Member States, are implementing more and more rules and regulations on climate change and air pollution, among them also ambitions for transport both in the private as well as in the public sector. Policy objectives are also increasingly ambitious, all to mitigate against climate change and air pollution. In the field of transport, the focus is ever more shifting from fossil fuels – on to transition fuels– towards zero-emission, all with the aim to reduce harmful emissions and advocating greener alternatives.

In August of 2019 the European Commission revised their previously published Clean Vehicle Directive, tightening up and set a minimum target for 24% of all public transport buses in each EU member state to be 'clean'[1] by 2025, with this minimum quota increasing based on the country's GDP. In the Netherlands, where one of the projects' sites is located the ambitions became even higher (during the time the project had already started and demonstration was ongoing), where the Dutch Government aims to have all new buses Zero-Emissions by 2025 and all public Transport buses Zero-Emission by 2030![2]

Due to the fact that public transport operations differs between countries, regions and even cities, a spread of zero-emission solutions is sought to replace the current fleets of buses. Hydrogen is one of the sought after solutions in heavy duty transport and therefore enjoying increasing attention from politics, giving political support, but also PTOs looking at the potential of the vehicles with fuel cell electric drivetrains. They use hydrogen as a fuel and produce no harmful tailpipe emissions, with a potential to create a zero emissions well-to-wheel transport system. Within the FCH-JU also a study was conducted on these fuel cell bus transport systems, which was published in the "Fuel Cell Electric Bus – Potential for Sustainable Public Transport in Europe".[3] Beside FCB also BEV buses can be used to reach the abovementioned goals, although in full public transport operation hydrogen can offer some advantages like fast refuelling times and longer ranges, making hydrogen interesting longer-range vehicles such as buses (high demand inner-city lines and regional outer city lines). Combining these facts, as these are the one that diesel buses offer now, hydrogen buses offer the same performance and operational flexibility, without impacting the standard customer service or time-schedules in which the current fleets operate.

Prior to the HighVLOCity project, hydrogen was showcased in prototype buses and demonstration projects, that showed the general public and other stakeholders the technology was working [CUTE and HyFleet Cute (>2001)]. These projects were followed by CHIC, where a first generation of commercial (although still prototypes) FCBs were demonstrated and the learnings and emerging conclusions triggered follow-up projects focused on further demonstration, technology improvements and larger scale bus fleets deployment, incorporating projects for their supporting HRSs.

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[1] Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles: https://eurlex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L1161&from=EN

[2] https://rwsduurzamemobiliteit.nl/praktijk-projecten/green-deals/bestuursakkoord-zero/

[3] Fuel Cell Electric Bus – Potential for Sustainable Public Transport in Europe: A study for the Fuel Cells and Hydrogen Joint Under https://www.fch.europa.eu/sites/default/files/150909_FINAL_Bus_Study_Report_OUT_0.PDF

In Figure 1, an evolution of the different bus projects is displayed in a timeline, including the CHIC, High V.Lo.City, HyTransit and 3Emotion projects, followed by the large scale implementation of large fleets in the JIVE and H2Bus Europe initiatives, surpassing the 1 to 2 digit numbers from the HighVLOCity project and reaching fleet sizes of 300-600 buses.

Projects also have even been combined and operated buses in parallel within the same city. A good example for this is the City of Aberdeen in Scotland that operated a fleet of 10 hydrogen buses in HyTransit and HighVLOCity. 6 buses (operated at stagecoach) and 4 buses (operated at First) combined (at that time) in Europes largest FCB fleet ran in the same city, fuelling at the same station.

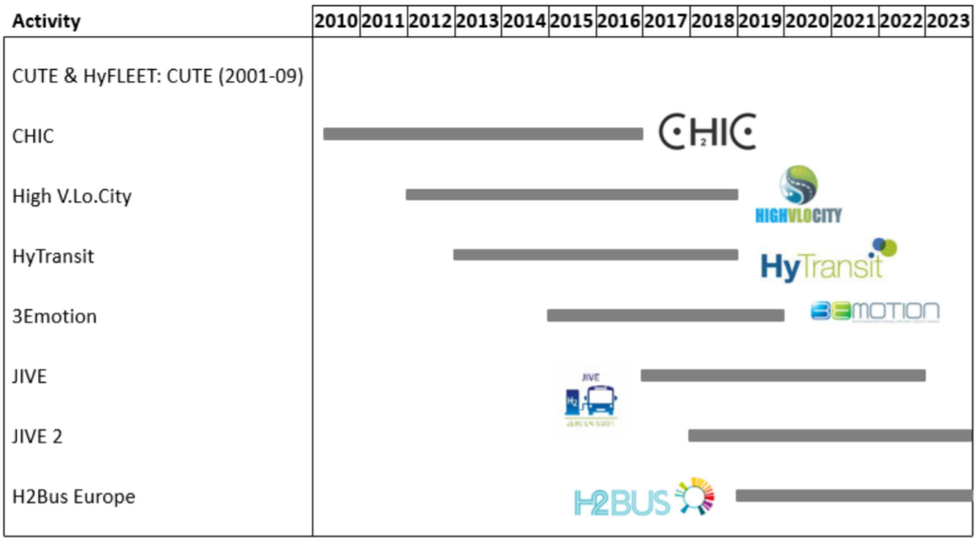


Figure 1: Source HyTransit final Report

HighVLOCity

The High V.LO-City project, through the use of, highly efficient, FCH buses and a comprehensive, modular maintenance and hydrogen infrastructure build-up, provided facilitated substitution of conventional buses in public transport fleets. Building on the arguments of the Public Transport (PT)Operators of the High V.LO-City demonstration sites, Liguria, Antwerp, Groningen and Aberdeen and of previous fuel cell bus demo sites, that led them to start substituting their conventional fleets with FCH buses, the High V.LO-City project further demonstrates the economic and technical viability of these buses and of intelligent infrastructure solutions, necessary for broad market introduction.

The project locations, with regards to past and future demonstration project cities, offered key stakeholders an important perspective for broader European-wide fuel cell and hydrogen business development and investment decisions, engaging with new industrial players to get involved in the advancing deployment of these technologies.

The project also included innovative solutions to current trends in the operations of public transport fleets that required great flexibility in refuelling and maintenance infrastructure. Modular build-up of refuelling infrastructure linked to low cost low carbon hydrogen sources as well as models for inter-modular fleet management, in combination with other modes of transport were tested as well.

Projects' objectives

The overall objective of High V.LO-City was to facilitate rapid deployment of the last generation of FCH buses in public transport operations, by addressing key environmental and operational concerns, that transport authorities are facing today. Through the strategic locations of the project demo sites the project envisioned broad dissemination of actual FCH bus performance in normal bus operations to other first time users and potentially interested transport authorities in their geographical area.
The detailed objectives of the High V.LO-City project were to:

1. **Implement** a fleet of **14** H2 hybrid FC commercial public **buses** in 4 regions across Europe with significantly enhanced fuel economy and high levels of availability, and with reduced maintenance and external technical input requirements
2. **Establish and enhance three hydrogen production and refuelling facilities**, linked to economical and sustainable hydrogen production plants, reducing the life cycle costs of H2 provision and transport
3. **Create a network of successful FCH bus operation sites**, so called **Clean Hydrogen Bus Centres of Excellence (CHBCE)**, linking High V.LO-City sites with similar fuel cell bus demonstrations in Europe, connecting regions form Italy, through Switzerland, Germany with Belgium, the Netherlands and the UK, to facilitate the dissemination of clear and factual information on hydrogen bus operations to transport authorities and key decision makers.
4. **Evaluate the entire life cycle costs of buses**, from their productions up the final operation aspects in view of the requirements of the EU Directive on the promotion of clean and energy efficient road transport vehicles (COM2009/33).
5. **Contribute to the commercialization** of H2 Hybrid buses in Europe, supporting the transferability of results achieved. High V.LO-City will set up business cases and Regional Mobility Plans as a success case and success models to be re-used in other European regions.
6. **Contribute to the standardisation** of authorization protocols for hydrogen refuelling infrastructure, through the analysis of existing experiences and existing barriers of national and regional regulatory frameworks in Europe.
7. **Facilitate EU objectives and policies** by researching and demonstrating the environmental, human health, energy efficiency, social and economic benefits of hydrogen powered buses in public transport,
8. **Pro-actively communicate project advantages** to citizens, communities, decision-makers and decision-formers so as to increase awareness, promotion, deployment and broader adoption of hydrogen fuelled vehicles, in particular for public and collective clean transport.

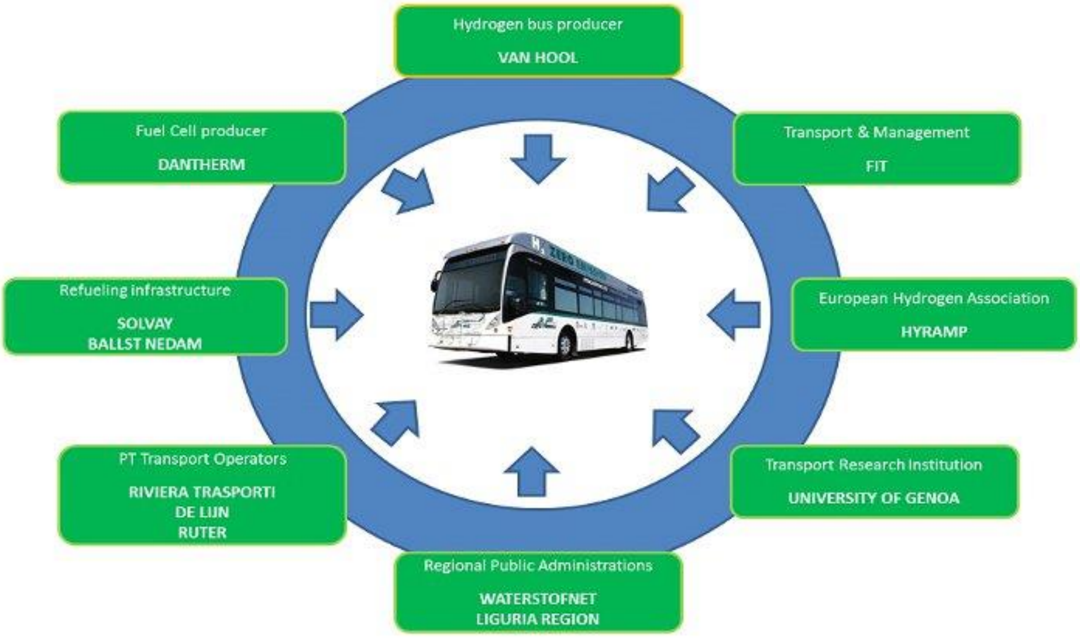


Figure 2: HighVLOCity Partnership roles in the project

Combining these objectives with a strong consortium of cross-Europe players, the HighVLOCity had a real versatile and experienced group of partners, that worked together to reach the set ambitions and objectives. Above, the figure displays the consortium partners split over the different disciplines to successfully execute the project. Below, the map displays the partners in the different regions across Europe working together in the HighVLOCity-project. The partnership included partners from Scotland, UK, Belgium, Netherlands, Italy and Denmark.

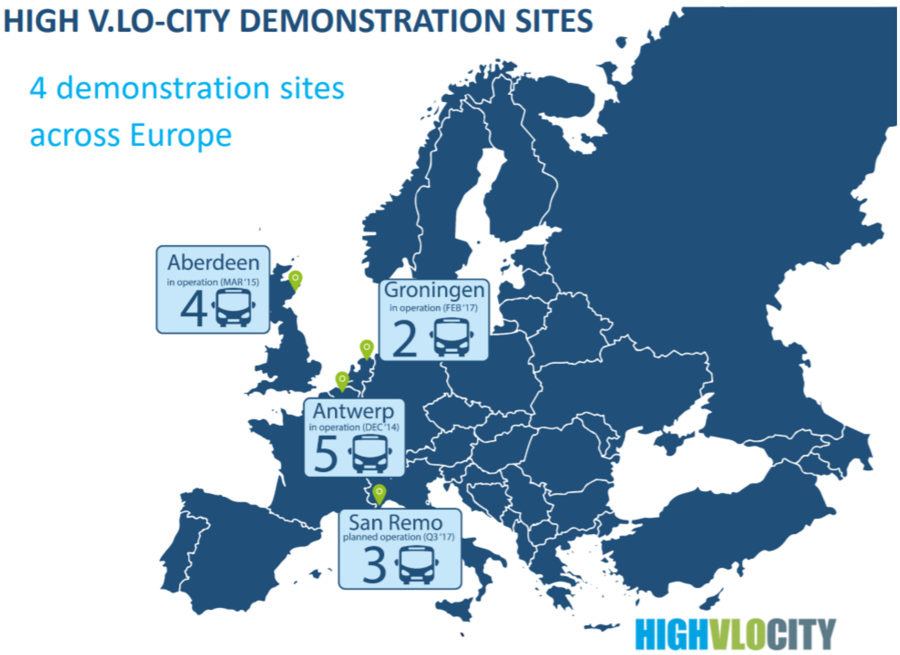


Figure 3: Demonstartion locations HighVLOCity

Main project results (Scientific and Technical results)

Project information and achievements

Project Context:

HighVLOCity	
Project duration	**1-1-2012 until 31-12-2019**
Number of partners	**12**
Total project budget	**30 494 110,49 €**
Total FCH-JU Contribution	**13 491 724 €**
Fuel Cell Buses demonstrated	**14 buses:** • Aberdeen (First Group) 4 pcs • Antwerp (DeLijn) 5pcs • Groningen (QBUZZ) 2 pcs • San Remo (Riviera Transporti) 3 pcs **Van Hool A330 hybrid fuel cell electric**: - Class I bus - right-& left hand drive - Passengers – 44 (seated) - Top speed: >80km/h - Hydrogen storage: 35-40kgs - Fuel economy >11km/kg - Range >350km - Fuel cell life >12,000 hours under warranty
Hydrogen Refueling Stations demonstrated	4 HRSs (3 with project funding) **Aberdeen Kittybrewster station:** - on-site hydrogen electrolyser (green electricity), capacity 300kg/day at 350bar, (3x 'Hydrogenics Hystat 60' on-site electrolysers. - 2x 'IC90 (Ionic Compressor) compression units' >~250kg/day. - Large high pressure storage (500-bar) storage to secure supply. - 2x dispensers capable of refuels at 350 bar. **Antwerp station:** **H2Station Bus 400** - On-site connection to hydrogen pipeline (<=100bar) - 1 compressor (400kgs/day) - 128 kg onsite storage @500 bar - 1 fast flow dispenser

	Delfzijl (Akzo) **PitPoint station:** - On-site connection to hydrogen pipeline (2bar) - 1 compressor (220kgs/day) - 150 kg onsite storage @450 bar - 1 fast flow dispenser **San Remo station** **AirLiquide:** - Trucked-in hydrogen via tube-trailer (200bar) - 2x Hofer membrane compressor (220kgs/day to 450 bar) - 160 kg onsite storage @400 bar - 1 fast flow dispenser

Overall assessment of project performance

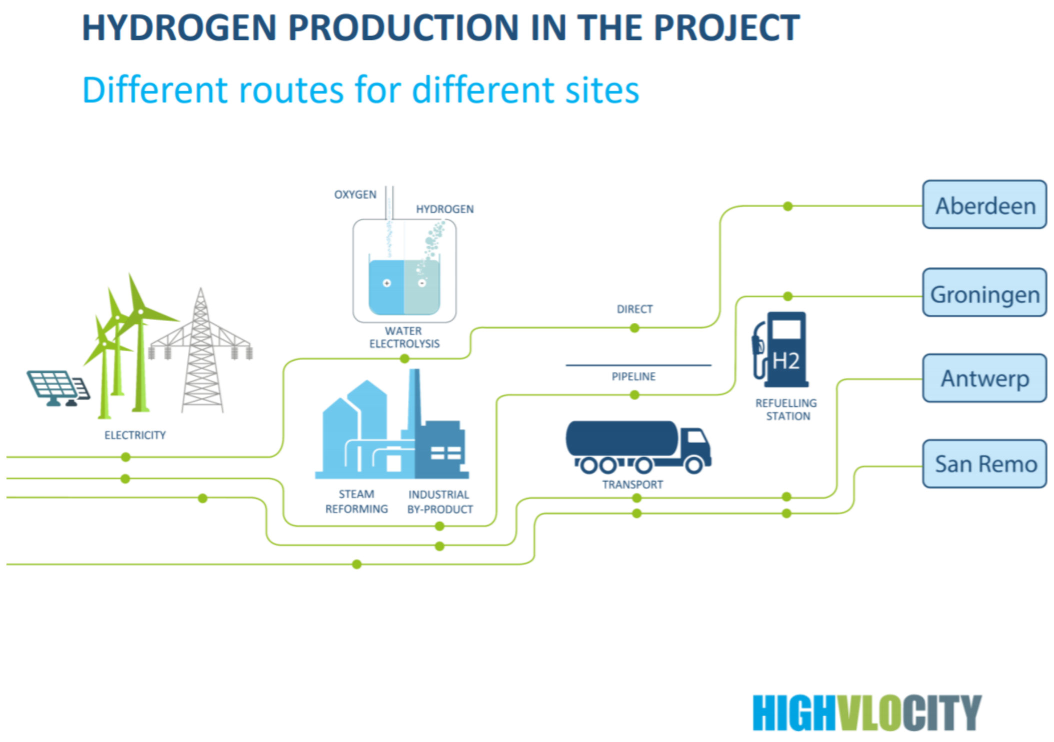
KPI	Target Call	HighVLOCity	Overall performance
Hydrogen buses			
Demonstration size	5 buses on each site	3 Sites (original) => 4 Sites, 14 buses	4 Sites (5,5,3,2 buses)
Cost of bus	reduction of 25% with respect to running buses	<1.3M €	1.1-1.3M€
Reliability of buses	600h	>12.000hr warranty	
Availability	>85% with maintenance	90% excl. Maintenance	>75% average
Fuel Consumption	11-13kg h2/100km	up to 7-9 kg H2/100km	9-13 kg H2/100km
Hydrogen Refuelling Stations			
Demonstartion size	1 HRS for each site	4 sites: 3HRSs in the project, 1 outside	4 HRSs
Refuelling station capacity	200kgs/day	300kg H2/day	285kg H2/day average
Availability of the HRS	98%	98%	96,80%
Station hydrogen production efficiency	50-70%	>65%	50%
Gas pressure	target n.a.	up to 570 bar	500 bar
Vehicles refuellingtime	target n.a.	10 mins	10-12 mins
Results			
Distance travelled by fleet			> 1Million kms
Fuel cell availability			>97%
Refuelling time			10-12 mins
CO2 emission savings			>1000T

Explanation of results

The main goal of the HighVLOCity project was to realise 3 sites, across Europe, to operate 14 next generation fuel cell electric buses in real life demonstrations. This project and the demonstrations raised the ambitions and challenging the OEM, component suppliers (FC) and infrastructure manufacturers and – operators make the next steps in development.
The main topics of improvements the project had to show:

- A reduction of hydrogen consumption of the buses to 7-9kg/100km;
- A reduction of the cost of hydrogen production;
- A reduction of the total cost of ownership of the buses;
- An increase of the overall operational availability
- An increase of the bus lifetime
- And to Contribute to a further commercialisation of FCEBs in Europe

Beside the operation of the vehicles and the deployment and operation of refuelling infrastructure, the project also included the showcase of different routes for hydrogen production and delivery within the 4 demonstration locations.



In upscaling scenarios, as also presented in the "New Bus ReFuelling for European Hydrogen Bus Depots - Guidance Document on Large Scale Hydrogen Bus Refuelling, released on March 15th in 2017[4] the choice of the delivery and production route is important. Partners in the HighVLOCity project also participated in this project and provided information and cases for their depots. (DeLijn, Aberdeen City Council)

[4] http://newbusfuel.eu/wp-content/uploads/2017/03/NewBusFuel_D4.3_Guidance-document-for-large-scale-hydrogen-refuelling_final.pdf

Combining all relevant operational data gathered in the projects' execution DiTen and the University of Genova performed environmental assessments and life-cycle-impact-comparisons, based on an ex-ante evaluation of the demonstration sites. Also conducting research on the local surveys and the social impact and – perception over the life cycle of the projects demonstration.

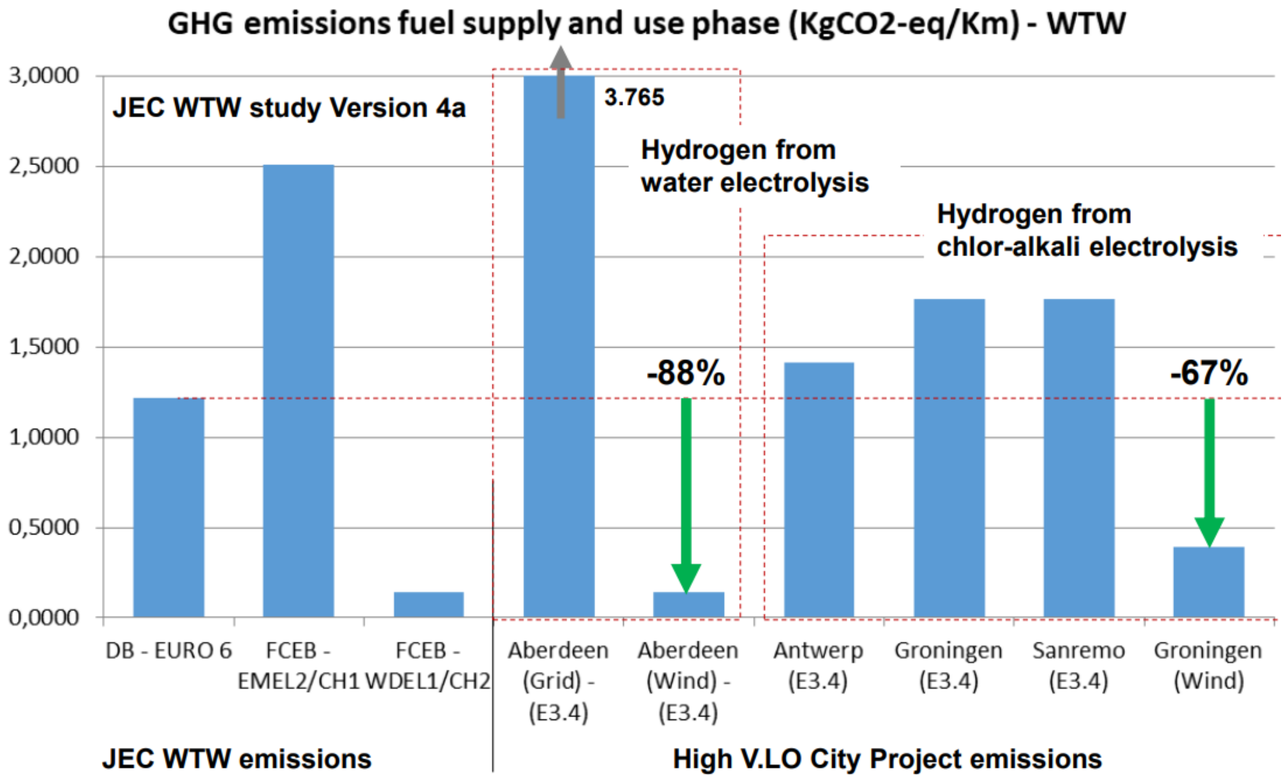


Figure 4: LCA: Greenhouse gas emissions from well to wheel

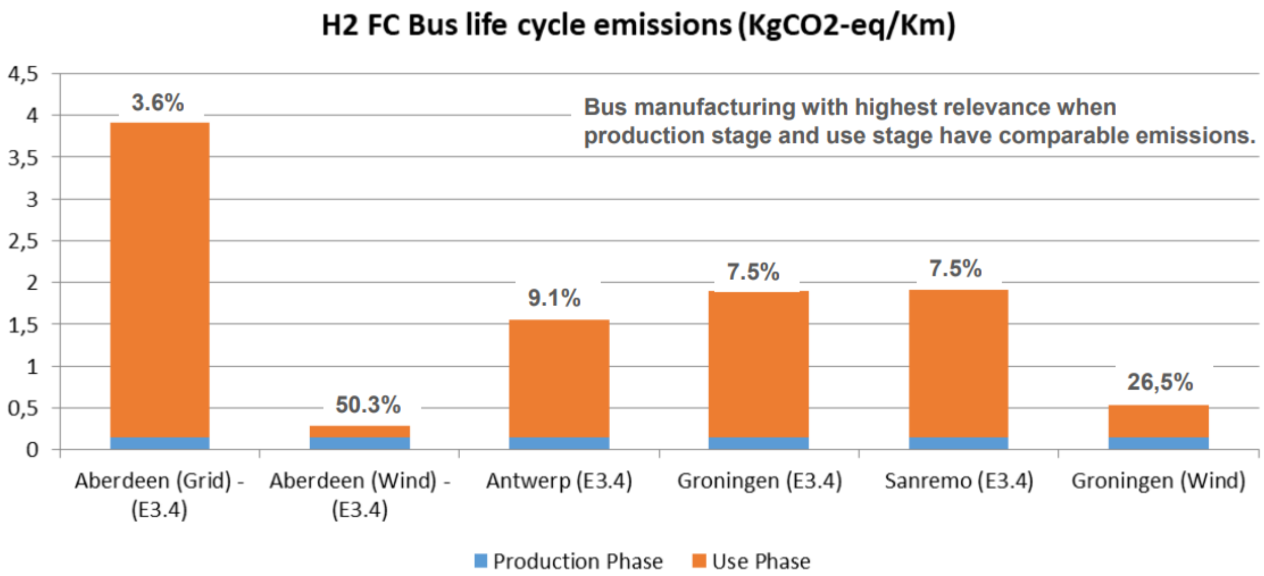


Figure 5: H2FC bus life cycle impacts comparison (av. fuel cons. 11.32 kg H2/100km)

Concluding remarks projects' environmental assessment

The results following on the assessments, executed within the project, clearly indicate, that it is advantageous to promote these modes of transportation in areas, where electricity is primarily produced from renewables (i.e. wind power as an alternative to fossil fuels).
It showed emission reductions of 67% and 88% w.r.t. a Diesel Bus.

The outcomes of these demonstration projects have substantially proved the effectiveness of such approach, thus favouring renewables penetration and improving significantly the air-quality in cities.

Life cycle perspective is essential due to shift of environmental burdens from the use phase (locally zero emission operation) to fuel supply chain

Renewable energy is the key to meeting increasing electricity demand and the decarburization targets in the generation mix

Fuel cell bus deployment and results

Aberdeen (>Mar '15)
Aberdeen City Council positioned themselves with the strategic aim to become 'a world-class energy hub, leading with a low carbon economy and be at the forefront of hydrogen technology in Europe'.

Local drivers for this can be found in:

- A highly skilled workforce in energy sector (oil and gas industry)
- Accustomed to the use of hydrogen in industrial processes
- Production of excess renewable energy (wind)

Policy drivers are:

- Reduce cross-sector greenhouse gas emissions by 42% by 2020 and 80% by 2050 (Scotland)
- Aberdeen City and Region Hydrogen Strategy 2015-2025

To make this a reality ACC developed a plan for a hydrogen economy, where public transportation with FCBs would play a large role. By participating in HighVLOCity and in parallel coordinating HyTransit.

Aberdeen city council became the centre of attention with regards to fuel cell operated bus fleets, as they (at that time) had Europe's largest operating fuel cell bus fleet, with 10 buses. 4 buses part of the HighVLOCity-project and 6 buses part of the HyTransit-project This large fleet also meant that the accompanying HRS would be very busy, fueling 10 buses every day, also making it the largest and heavily used HRS in Europe, with a high availability of 99.7%

In both HighVLOCity as well as HyTransit the mileage of the buses during daily operation was high and the buses were used extensively. Operation of the hydrogen buse fleet will also be extended with > 10 additional buses in the JIVE project.

Antwerp (>Dec '14)
Antwerp was the first site to become operational within the HighVLOCity-project operating a bus fleet of 5 buses (>Dec '14) . The public transport operator for Flanders, DeLijn, operates the buses in the city of Antwerp, running service in the northern part of the city, due to the choice of the HRS location in the Antwerp Harbour.

As the PTO for the complete region of Flanders, DeLijn is always investing in clean public transport with a focus on sustainability. This focus is broader than only the hydrogen buses and also takes into account the tests with full battery electric and diesel hybrid buses. The investments in fuel cell electric buses corresponds to the vision of the Flemish government to reduce emissions from road transport and is also born as a necessity to the long range some of the city lines need to drive on a daily basis.

During the project it became more and more clear that the location of the HRS, not being on the depot(>20kms), became a bottleneck for a good service and operation of the different lines, operated with the 5 FCBs. This non-bus related issues as well as the structural shortage of qualified drivers were affecting the ambitions and goals of the site. Affecting the daily mileage and even the buses going into service in the morning, showing lower percentages of usage. Nevertheless DeLijn operated the buses on a regular basis resulting in almost 300.000kms driven in service.

Groningen (Feb'17)

Figure 6 source: fd.nl

Groningen was the last site to be added to the consortium. After financial difficulties at Riviera Transporti in Italy and the fact that they were not able anymore to step up to the expectations to start operation of a fleet of 5 FCBs, 2 of these buses were relocated to Groningen, to QBuzz. After the buses received a overhaul and a rebranding to the corporate identity of QBuzz the buses were put into operation in February of 2017.

Groningen, in the North of the Netherlands has large ambitions with setting up a hydrogen economy in the Northern Provinces of the Netherlands. Beside the fact that current gas extraction is scaling down, a move to renewables is getting stronger and they also want to pre-sort on the changing environment and the political ambitions in zero-emission transport *(From 2025 onwards, all buses should be zero emission)*, made them to choose to enter the project, which was already running. QBuzz is the private bus company, executing public transport operation in the north of the Netherlands. They are a very worthy addition to the project sites, generating a lot of attention for the buses!

QBuzz is operating the buses in suburban routes with a high daily mileage, a high average speed and lower stop frequency. The buses are performing very well and the highly demanding routes are nearing the operation of the Aberdeen buses in HyTransit.

San Remo (Dec '18)

San Remo is one of the sites that initiated the project and showed a high potential for using hydrogen buses in their transport system. In San Remo a Trolleybus system is in place since 1942 and this system (although it emits very low emission from the buses) shows high infrastructural maintenance cost and a low flexibility. In this case FCBS show a high potential for a suitable zero-emission solution that gradually could replace trolley buses.

Initially the project envisioned a fleet of 5 FCBs, but due to financial difficulties and restructuring of the organisation, this was not feasible anymore. Therefore it was decided together with the FCH-JU and the project consortium to find a new location for of the buses, that eventually went to QBuzz in Groningen.

After the buses received a technical check-up and exchange of some defect parts the buses returned to Italy and could start operation when the HRS became operational in the 3rd quarter of 2018. The 3 buses are operated on a sub-urban line, where each bus drives 300kms/day

Results for all sites:

Adding all the above mentioned buses and operational results together, a combined chart can be made for the operation of the 14 FCBs within the HighVLOCity project. Data has been collected on the buses for almost the full duration of the project for all buses. (Unfortunately, only data from the San Remo buses is missing regarding hydrogen consumption)

In the figures below, one can find the odometer readings of all the buses of the HighVLOCity project, added with data coming from the same generation buses of VanHool, operated in other locations in Europe,(HyTransit- project => Stagecoach, and in Cologne =>RVK) followed by hydrogen consumption data of the different sites. These data set and graphs presented below, show the operation and differences in operation of a fuel cell bus fleet at the different city locations. Some can be lead back to geographical-, climate- and operational conditions (like driver training on eco-driving). The individual affect of drivers wasn't taken into account due to the private character of this data, but it has been noticed and also seen on normal diesel buses, that the driver also has a significant role in the consumption of a bus.

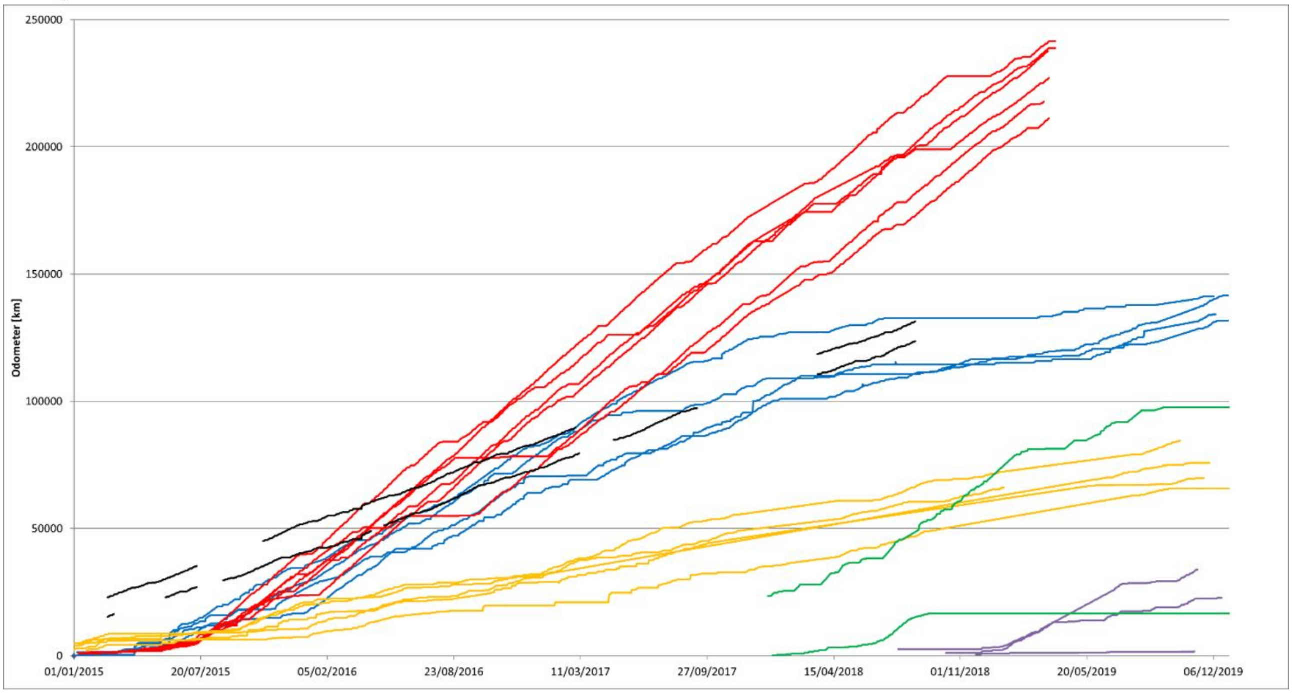
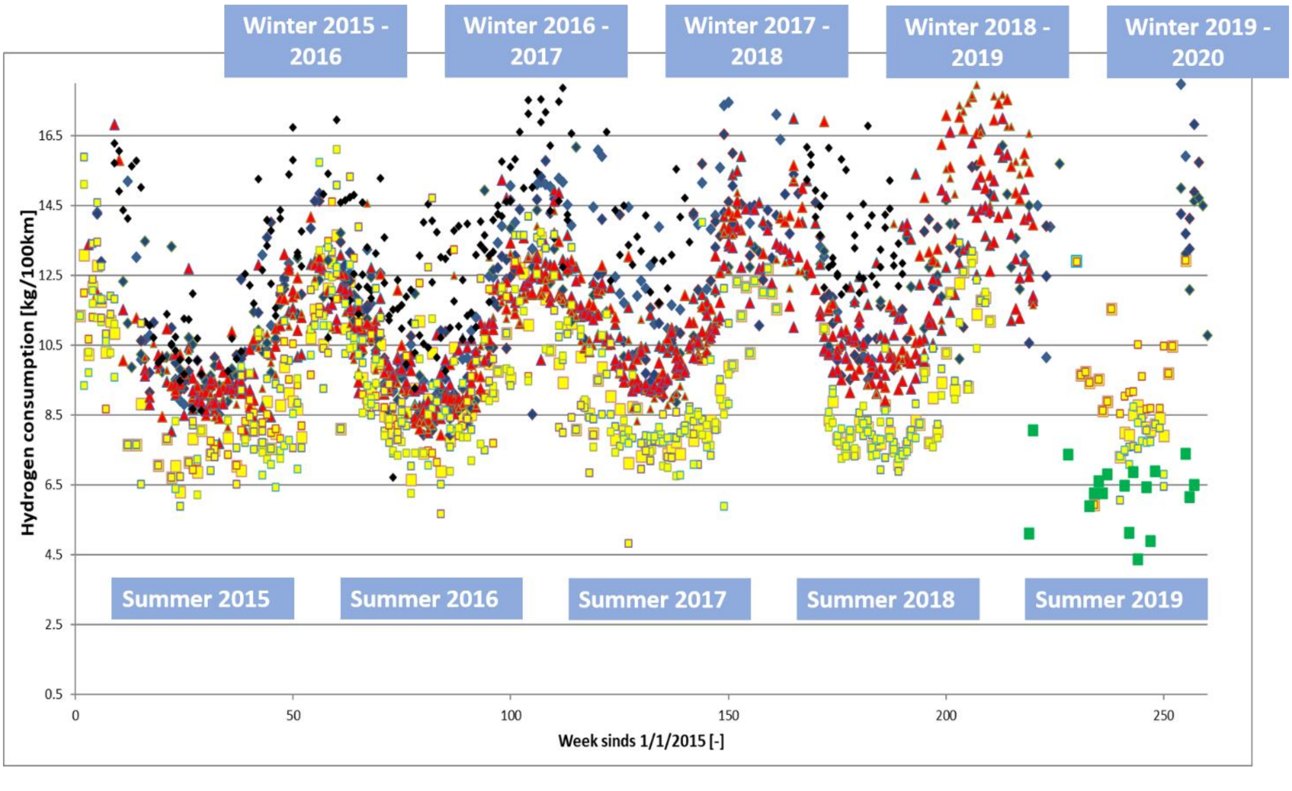


***Figure:** Evolution of odometers of Van Hool HD6 buses. Red lines: Stagecoach, Blue lines: First, Yellow lines: DeLijn, Black lines: RVK, green lines: QBuzz, Purple lines: Sanremo. Remark that the odometer in one of the Qbuzz buses stopped functioning 12/09/2018*

In the figure below the individual sites and their average consumption of the buses throughout the HighVLOCity-project, is shown, also displaying the deviations in summer and winter conditions of the different sites. (San Remo buses not included, due to loss of data by malfunctioning data-transfer of data-logger)



Odometer findings

As seen in the odometer graph, the separate bus demonstration sites of HighVLOCity, were also combined with odometer data from RVK (in Cologne) and the HyTransit buses (which stopped operation in early 2019.

The overall trend is that the buses are quite well used, one can also see the difference in Aberdeen, where the same buses in the same city, differ in mileage driven on a day/ month at the 2 PTOs. The Stagecoach buses show a larger slope than the first buses. In Antwerp one can also see that the daily operational kms are lower than the Scottish example, reasons for this have been described previously, "HRS location" and "lack of drivers".

The operation in Groningen, beside the fact that one of the buses had a defect on the odo meter, shows a steep climb, where a lot of kms are driven on a daily basis, exceeding the buses in Antwerp.

In San Remo, where the buses became operational last one can also notice an extensive usage of the buses, showing the same kind of graph as the Groningen buses. This is also due to the fact that both the San Remo site as well as the Groningen site are using the buses mostly outside the city in the country side. This characterizes in a higher daily mileage, a higher average speed and less stops in comparison to buses only used within the city boundaries. Unfortunately one of the San Remo buses has driven a lot less kilometres than anticipated. In San Remo financial problems at Riviera Transporti have plagued the project since the start, which also meant that during the project maintenance was done on a risk-based maintenance strategy. One of the buses had technical issues that needed to be solved internally as well as with VanHool, but without a proper maintenance agreement, this bus suffered from a problem that was not fixed in the project period. Despite the official event of the RT experiment was in November 2018 (to be able to engage several public officers), the first runs of the buses (without citizens and for testing and training) started in early Q3 2018

All in all the graph shows the different usage and operational profile of the buses, inner-city use, sub-urban usage and countryside usage. Technically one can also see the unavailability and also the sensitivity of a datalogger, which meant that some buses didn't transfer the data to the servers anymore. It has to be said, in comparison to previous projects manual data collection is not feasible anymore when the project and the fleets are getting bigger, but logging has to work correctly and without problems.

Consumption findings

Within the graph a clear winter & summer trend is visible, where vehicles are consuming more in the winter than in the summertime. One of the main reasons is to be found in the fact that the heating of a bus consumes (extra) energy in comparison to the rest of the year. The buses in Aberdeen in HighVLOCity didn't use air-conditioning. This partly explains the decline in consumption after the wintertime, where no heating is used to heat up the bus anymore, but also shows that heating has a larger energy impact in the winter, than air-conditioning in the summer. One still sees a seasonal fluctuation throughout the year.

What also can be noticed is the upward trend of the consumption across the fleet over time and also a larger variation becomes visible as the buses age. This effect is especially noticeable among the vehicles, that are used intensively (sites First, Stagecoach and RVK). In all likelihood, this can be linked to a decreasing efficiency of the Fuel cell.

Finally, you see that De Lijn and QBuzz consume less in average, than the other displayed sites. For De Lijn this can be lead back to the relatively long distance between the petrol station and the depot (40 km on a daily basis), which is travelled at a higher speed and without passengers (empty bus): this reduces the average consumption values significantly.
Finally, the QBuzz buses are also traveling at an higher average operational speed and far little “city traffic” compared to the other sites, driving in rural and country-side areas. This also results in a lower, visible consumption. In fact the QBuzz buses also showed a high daily mileage, combined with the lower consumption this also means a high range of kms for these buses.

In overall for the entire project, two main problems have been popped up related with daily operations of fuel cell buses:

- Although all of the sites (with exception of Groningen) received initial training for the use, fuelling and maintenance of the buses, it was considered necessary to do repeat- or follow-up training courses. This really helped in increasing the mileage as familiarity with the buses as well as the HRS increased, especially in the Aberdeen site, but also the case for San Remo where the training took place at the first delivery of the buses. There was some time in between the first delivery and (final) start of the operation in late 2018.

- Especially in Antwerp, some non-bus related issues were supressing the operation of the Fuel Cell buses: the shortage of qualified drivers and the distance between the fuelling station and the closed service lines have still been adversely affecting the mileage, as both management and drivers seem to struggle with this complexity. Also the city is undergoing large roadworks near the depot and on the routes, meaning that the buses, even operated also had challenging difficulties on-route.

Conclusions

- A introduction of Fuel Cell Buses in daily operation needs to be done in a smooth manor, step-by-step. Introducing new technology can cause operational stress, if not done correctly
- One should ensure that there is an efficient supply chain in place, keeping for example spare parts onsite at the depot.
- A direct relationship between bus manufacturer and bus operator is vital to ensure the quick resolution of problems.
- Training of drivers and technicians is essential before the operation, but as important during the operational part of the project.
- Customer acceptance, both from the drivers as from the passengers, was very good. Both enjoyed the buses and highlighted the quieter and smoother drive in comparison to conventional buses.

Milestones:

- Total driving distance covered: **>1.000.000 kms driven**
- Consumption (average): **9 - 13 kg H2 /100km**
- CO2 savings: **> 1000T CO2 emissions saved**
- FC availability: **>97%**
- Bus availability: **>75%**

Hydrogen refuelingstation deployment

Aberdeen (Feb ’15)

ACC contracted BOC-Linde to build the Kittybrewster HRS into a small urban bus depot. The layout of the Kittybrewster site, and its location in a built-up residential area, meant that innovative and original designs for the station had to be drawn to minimise the footprint of the HRS. On top of this the station had to daily supply 10 FCBs with a high availability. Being the first HRS in the North of the UK and having no sufficient supply of hydrogen, the system had to be built with on-site generation of hydrogen at a high redundancy, hence using 3 electrolysers, 2 compressor 2 dispensers and an overcapacity of storage to be able to further operate the station even when in maintenance.
The key of successful bus operation lies at a reliable fuel supply system.

Permitting, civil works and construction went expeditious mainly through the strict and timely project management of ACC together with the supplier BOC.

Antwerp (Jan ’14)

The station in Antwerp, differs from the Aberdeen system, being placed in the Antwerp harbour near a hydrogen generation plant, that feeds the hydrogen pipeline of AirLiquide. This pipeline stretches from Rotterdam to Dunkerque and provides hydrogen to industry.

At Solvay, whom is using a chlorine electrolyser plant to produce chlorine, hydrogen is a by-product, which can be used for transport, for example buses. The quality grade is high to be directly used in fuel cell applications.

The Flemisch transport operator DeLijn, agreed with Solvay to place the HRS at this location to fuel the fleet of 5 buses. Solvay (at that time) bought the station at H2Logic, later NEL and the station, a containerised solution with 2 compressors, storage and in built-in dispenser. The permit was granted quite easily, the civil works also meant to forsee a connection to the pipeline and the container was then placed on top of the pipe-line. Hydrogen from this pipeline is compressed, stored and fueled in the buses. The station opened in January of 2014

After some time, operations with the buses noticed that this choice, driving with the buses to the station and back was a time consuming activity and also meant that the bus was not fully fueled when arriving at the depot. In the meantime PitPoint took over the HRS from NEL and plans were made to relocate the station to one of the depots of DeLijn in Antwerp, the choice was made for “de Vaartkaai”. A new permit request was handed in. During this new request it turned out that the Environmental permit for the depot itself had expired and that a new permit had to be requested. Although allowed and civil works started and completed, the process for getting the environmental permit for the depot took longer than expected and lasted longer than the final date of the project.

The relocation of the HRS will take place after the projects’ closure. Operation of the buses and the station unfortunately suffered from this.

Although it also has to be said, that the station performed well and showed also a very high availability and reliability for fueling the buses.

Groningen (Feb ’18)

QBuzz arriving late in the project as a partner, whom wanted to operate 2 FCBs available from the San Remo site. To be able to operate these buses a HRS location and supplier needed to be found. In Delfzijl, to the east of Groningen, Akzo-Nobel owns an industrial plant operating a large elctrolyser. At this plant, similar to Antwerp the electrolyser also produces high quality fuel cell grade hydrogen. Together with the partner PitPoint it was decided to build an HRS beside the industrial area adjacent to the public road.

Here it was also decided to use a containerised concept of a HRS, where the station was connected to the local hydrogen pipeline, feeding the compressor, storing the hydrogen and fueling the buses. PitPoint, whom already had experience with 2 HRSs was able to build the station in a short time and operation followed soon after the permit was granted and commissioning completed.

This station was the smallest of the project, because it only needed to refuel 2 buses. Nevertheless it also showed a high reliability and an availability of 99%

San Remo (Oct '18)
Although San Remo, partner from the first hour, was proceeding quite well in the beginning of the project, the station to refuel the 3 Riviera Transporti buses was the last one to start operations under the HighVLOCity project.

The location siting of the HRS, North of the city, was chosen due to strict regulations as well as the fact that the city of San Remo itself is quite densely populated and space is scarce, therefore a site outside the city was chosen, near the methane distribution plant of the city.

The Site Acceptance Test was finished in 25-10-2018 and the station went in operation in the first days of December of 2018. Initially, it was initially also designed with its own on-site production of hydrogen by electrolyses, producing and storing the hydrogen. For economical reason, the project was reduced and the electrolyser was cancelled.

The station was built by and with AirLiquide (Italian devision) which also operates the station. The station consists of 2 compressors, 250 kg storage and 1 fast flow dispenser. Hydrogen is now supplied by tube-trailer, which is also stationary at the HRS as a mobile storage.

The station at the start endured some teething problems and it took some time to solve these, but eventually the station performed well, providing hydrogen for at least 2 of the 3 buses.
The station , due to the late start could not reach the average availability numbers of the other 3 stations, but wasn't performing a lot less.

	Antwerp	Aberdeen	San Remo	Delfzijl
Total amount of refuellings	1810	2506	141	672
Total amount of hydrogen refuelled	30,324 kg	55,736 kg	5596 kg	15,194 kg
Average refuelled quantity	16.76 kg	22.24 kg	39.68	23.01 kg
Overall availability	99%	99%	92%	99%

Conclusions

- Refuelling a bus takes approximately 12 minutes, just like a conventional bus.
- Presence of a local operation manager is vital to achieve a high availability
- Stations are more efficient when being used at high/ full capacity
- Fuelingstation technology shows maturity and a high reliability resulting in a high availability.
- Refuelling station should be located close to the bus depot to ensure an efficient operation.
- Hydrogen production requires considerably more energy, therefore blending network supply and renewables is a viable schema for the roll-out of hydrogen refuelling stations at larger scale, without compromising the existing infrastructure.
- For the future of hydrogen and the cost aspects, hydrogen should also become cheaper and prices need to be competitive with diesel.

Milestones

- Fuelling time (full tank): **10-12minutes**
- Availability (average): **96,8%**
- Showcasing a mix of hydrogen delivery-systems to the stations

Challenges encountered:

During an innovative demonstration project, working with new technology, pioneering new grounds, working with different aspects of a transport system and working together in a partnership with partners coming from different regions, having different backgrounds and experience, operating (in this case) public transport differently, will throw up challenges.

After a project, that lasted for 8 years, twice the life-time it initially would last, the consortium encountered a lot of challenges, draw-backs, postponements but most of all learned from these.

The most important combined challenges, all sites also had their specific challenges, were listed in the final conference. Five main points were said to be the most common and thought to be important after questioning every partner (OEM, HRS supplier, PTO and regional organisation).

The project encountered technical failures and even a lower than expected availability of the buses. This improved during the second half of the project and after the individual teething periods. It is also expected to improve even more with new generations of buses.

Suffering from delays in the supply chain was also challenging and seeking a solution for this. Therefore the strategy was adopted to by storing spare parts at the local operators, mitigating the problem of long delivery times. This will also improve when more buses are deployed in Europe and spare parts are commonly available.

What was underestimated was the external factors impacting the performance of the buses, lack of drivers for instance. Training therefore is key, before and during the introduction and operation of the buses.

Data collection issues encountered, sometimes even resulted in data losses. In HighVLOCity a lot of data collection was still retrieved manually (SD-cards) which have a higher chance on errors and better dataloggers need to be implemented in next generation of buses.
Last would be the siting or location of the HRS. Ideally the HRS is located on or near the depot, to have the shortest distance to refuel. When infrastructure outside the depot or far from the depot is used, operators miss valuable kms in operation and drivers need and loose time to fuel the bus after their shift. This is also noted as a undesired effect where driver don't want to go refuelling the bus, after the shift ended.

<u>Post-project site developments</u>

HighVLOCity, granted in 2011, started in 2012, lead the way for the next wave of demonstration of fuel cell buses after the Cute, HyFleet Cute and operating in parallel to CHIC whom started earlier. In the years HighVLOCity was running, 3Emotion started and the level playing field of hydrogen buses changed. More and more environmental regulations were implemented and the importance of zero-emission transport is a necessity. In the meantime also the projects JIVE 1&2 have started combined with the large scale infrastructure project Mehrlin and the H2Bus Europe project, growing from 5 buses per location to 10, 20 or more buses per location.

This is also the case for the sites, that operate(d) buses in HighVLOCity.
The site of Aberdeen is participating in Jive and will receive at least 10 more FCBs, operating a larger fleet than before.

QBuzz operating in Groningen reached a high level of confidence to make the next step in scaling up and is now also participating in Jive receiving 20 additional buses, another 10 buses will go to the neighbouring province of Drenthe after the learning about the HighVLOCity experiences of QBUZZ.

San Remo will keep operating their fleet of 3 buses, but due to the financial situation it is unclear if Riviera Transporti can keep their initial plan to replace the trolley bus transport system for a fuel cell and hydrogen bus transport system.

DeLijn is awaiting the final approval of their depot environmental permit to start relocating the HRS from the Solvay location to their depot at "de Vaartkaai". Commissioning the HRS onsite and restart full operations with the 5 FCBs

It has also to be noted that during the years and through the project bus prices, HRS prices and component prices have gone down through the scaling-up effect and that more and more cities are now lining up to start operations with fuel cell buses. Some cities have closely followed up on the HighVLOCity project and now entered the consortia of 3Emotion or JIVE.

The potential impact, major dissemination activities and exploitation of results

In comparison to previous successful EU fuel cell bus demonstration projects as CUTE and HyFLEET:CUTE projects, the activities in High V.LO-CITY project, instead of focussing on primarily testing the buses' performance and refuelling operations, was in demonstrating a clear FCH bus value proposition to transport authorities and policy makers in order to accelerate commercialisation. The High V.LO-City dissemination efforts were therefore concentrated on reaching a large number of decision makers and the general public to accelerate FCH bus acquisition in the near future.

At the start of the project three levels of dissemination were identified, to determine the type of information to be shared with each target group: 'Inform' represents the lowest level of dissemination: general information about the project and the fuel cell technology that could be communicated to the general public. 'Promote' represents a more targeted level of dissemination aimed at policy makers, transport operators and the FCB industry. This encompasses the overarching results and learnings of the project, with the aim to increase the larger uptake of FCB and hydrogen technology across Europe. 'Engage' represents the highest level of dissemination. This includes detailed information about the performance of the buses and the refuelling infrastructure which could be shared with policy makers and transport operators

In order to ensure a coordinated approach, leverage communication efforts and budgets the High VLO-City dissemination activities had a close alignment with CHIC's project dissemination (during its project period) and later with 3Emotion in targeting the so-called Phase 2 cities as well as broaden communications to a larger group of public authorities throughout Europe. Phase 2 cities in the CHIC project had already communicated an interest in future FCH bus acquisition. The High V.LO-City project through focussed dissemination provided technical information on the operation of the buses and the refuelling infrastructure as well as on the impact of the use of FCH buses on local air pollution and CO2 reduction to an additional number of transport authorities in the specific High V.LO-City but also 3Emotion countries, as well as to locations on corridors that are linking the current FCH bus demo locations of the FCH projects.

In all High V.LO-City locations it was the first time that FCH buses were put in regular operation, for High V.LO-City therefore the focus on dissemination defined 3 main goals:

1. Communicating the location's role as a front runner in implementing zero emission bus technology in their area in order to engage neighbouring cities to join;
2. Informing a large number of EU and national stakeholders about the increasing number of local transport authorities involved in FCH bus operations;
3. Building increased visibility of FCH buses at relevant industry, public transport and local authority events in close collaboration with the FCH JU programme office, CHIC and HyER members.

Dissemination played a crucial role in the HighVLOCity project, disseminating the experiences and results of operating the buses, the project results and data monitoring outcomes as well as the lessons learned from the project. The main goal was to ensure that these results would be disseminated widely, using existing and new communication channels, as well as the different dissemination tools developed in the project.

Communication channels and dissemination tools used and developed within the project are:

- The HighVLOCity project logo
- The HighVLOCity project website
- The fuelcell busses knowledge base website (now also the project website for JIVE)
- HighVLOCity Leaflets
- And combined social media spread of messages via linked-in and twitter (@fuelcellbus)

Project logo:

Branding:

Throughout the project the branding is important to distinguish the project from others and to harmonise and link the different partners and European sites under one umbrella. In the demonstration phase all buses received their corporate branding, combined with the HighVLOCity branding and FC-JU logo's, an example from QBuzz on the logo incorporated in the company branding is shown right. Always accompanied with the correct and obligatory branding of the FCH-JU

Project website

The first link to the project, for the outside world and stakeholders is the official project website, which informs the visitors on the project, its objectives and goals, updates on the project locations and the latest news on the progress and or events. And gathered all the project relevant media attention, in the media corner.

The High V.LO-City website has been set up early in the first reporting period of the project and has been updated regularly. Adding news, photos and articles. During the last part of the

project, the main objectives of the projects were to publish news on the website as regularly as possible, as well as improving or updating some of the core content of the website. New material was added to the website when available. As a result, the website is more comprehensive and more interactive, therefore attracting more visitors.
Furthermore all the project news were also published on the Fuel Cell Buses website

Leaflets

During the course of the project also a handful versions of a project leaflet were produced. And a final version of the leaflet was created before the final conference of HighVLOCity to showcase the results and summarize the project in a few words and graphs.

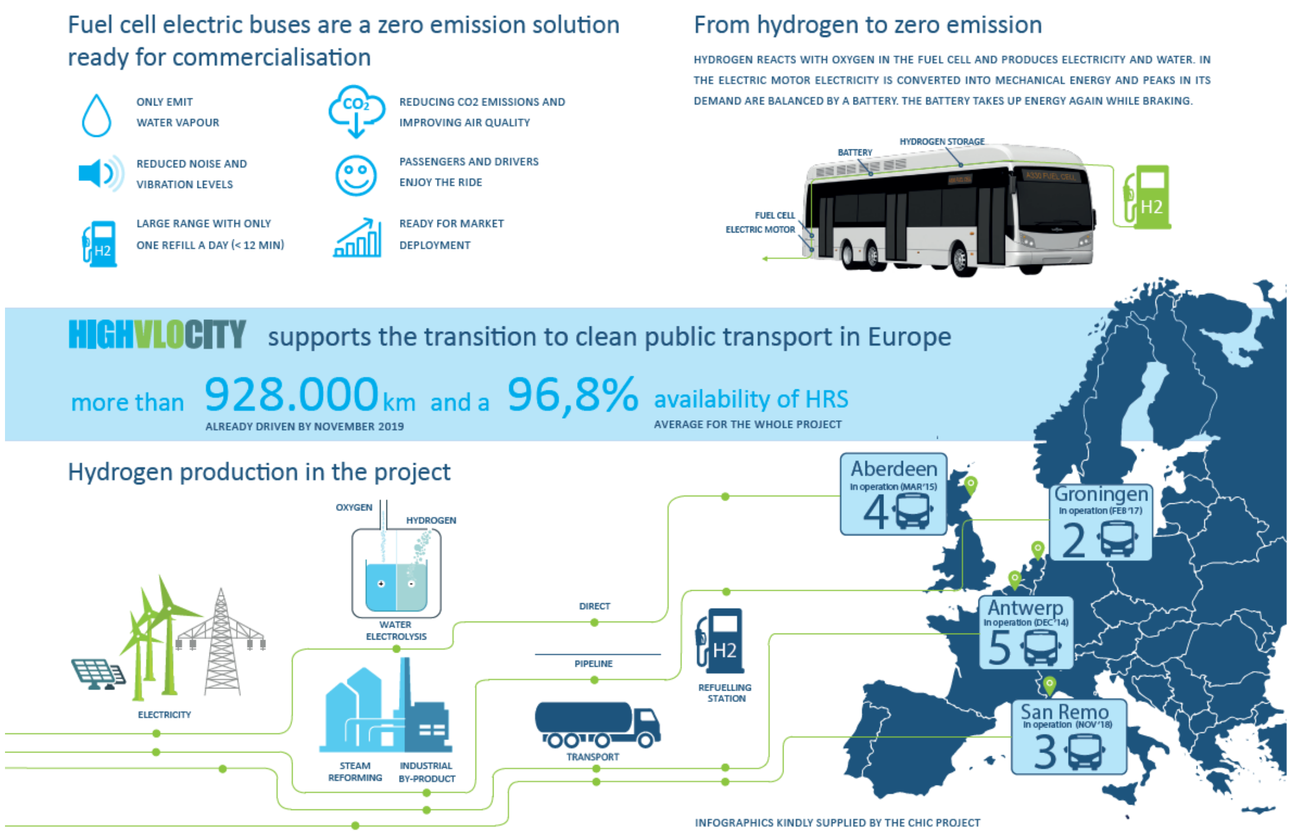


Figure 7: Final project leaflet

Fuel cell buses knowledge portal a digital hydrogen centres of excellence

In the project application, the creation of a physical centre of excellence was originally foreseen for each of the deployment sites. After the start of the project, partners came to the realisation that creating a physical space for dissemination would;

- Not be a realistically achievable objective
- Limit the outreach of the Centres of Excellence to the cities and regions where buses are deployed through the project.

It was therefore decided to replace the physical Centres of Excellence by virtual Centre of Excellence, which would serve as a knowledge base for fuel cell buses in Europe. This led to the creation of the fuel cell buses website (www.fuelcellbuses.eu), in close collaboration with the other FCH-JU fuel cell bus projects.

Fuel cell buses Knowledge Base - The website for fuel cell buses was developed as part of the High V.LO-City project to provide a consolidated base for all knowledge on FCBs. The website, www.fuelcellbuses.eu, gathers comprehensive information about fuel cell bus demonstration projects in Europe including information about the buses deployed, locations, data, reports etc. Dissemination activities

The website was improved and continuously updated during the last part of the project. A twitter feed, a news section and an events section were added to the website to make it more dynamic and encourage viewers to visit the website more regularly. An interactive map now also showcases all the fuel cell buses deployed or to be deployed in the next few months in Europe. These changes and additions required the website to be updated a lot more regularly, especially the news section.

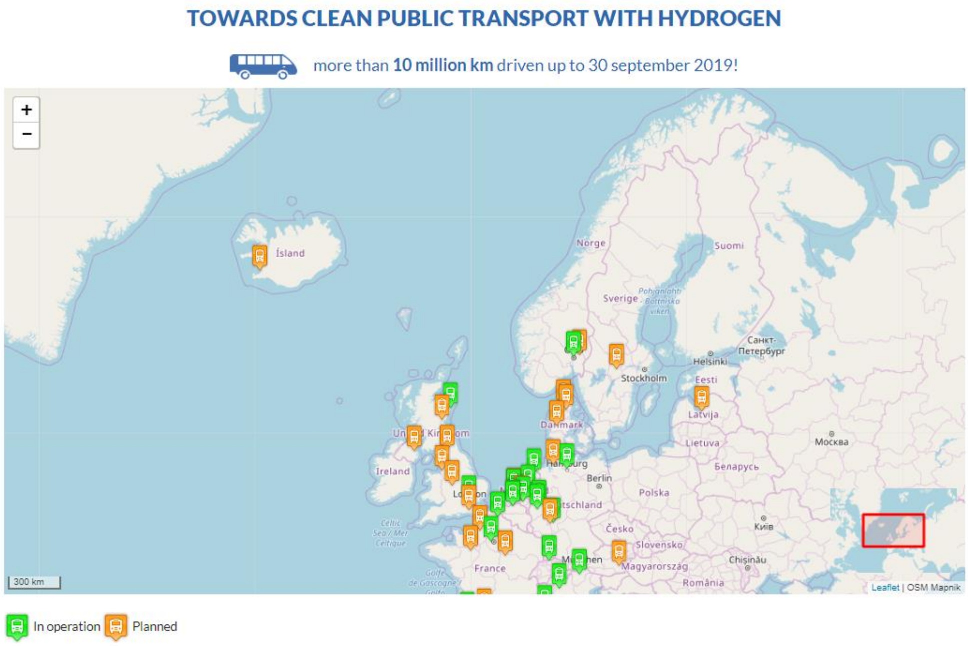


Figure 8: Screenshot: www.fuelcellbuses.eu ; interactive map

Figure 9:Screenshot: www.fuelcellbuses.eu ; news and events section

During the course of the project HighVLOCity itself hosted events, among them the mid-term conference and the final conference, celebrated the official openings of all 4 demonstration sites in Antwerp, Aberdeen, Groningen and San Remo, presented the project and its results on national and international podia (ZEB-conference), exhibitions and fairs. Some events even received media coverage.

Beside these centrally organised events, also project-partners themselves organised smaller events or showcased the buses at other events or gatherings. QBuzz even transported the Dutch Prime Minister at an event in Groningen Below a small selection of images.

The elaborate list of Dissemination activities can be found in the Annexed Section A.A2

Project public website

http://www.highvlocity.eu/

Figure 10:Screenshot of the HighVLOCity project website

IMPORTANT NOTE:

Also linked to the HighVLOCity-project website it should also be noted, that the fuel cell bus knowledge portal, as part of a project deliverable and the projects' strategy to create an international centre of excellence or "one-stop-shop", is also part of this. The portal, now included and merged together with the project website of JIVE can be found under:

http://www.fuelcellbuses.eu

Figure 11:screenshot of fuelcellbuses knowledge-base

List of all beneficiaries

Organisation	Name	Contact details
VanHool	Dirk Amereijckx	Geert.van.hecke@vanhool.com
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Ballard Power Systems	Kristina Floche Juelsgaard	Kristina Fløche Juelsgaard | Business Development Director
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Annex: Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of results (section 4.3. - H).

The plan should consist of:

- Section A This section should describe the dissemination measures, including any scientific publications relating to foreground. Its content will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the FCH JU. Information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

- Section A (public) This section includes two templates:
  - Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
  - Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

Section A:

A1) List of scientific publications

In total 5 Articles have been produced, 1 has been submitted (see picture) and 4 have been published. The latter are not publicly accessible, because of publisher's licence agreement (the proceedings are available by payment).

<u>The submitted article:</u>

International Journal of Sustainable Transportation. Submitted in September 2019. " Environmental performance of fuel cell buses: a Well-to-Wheel assessment of greenhouse emissions". Authors: Cristina Carnevali , Adriana del Borghi, Michela Gallo, Riccardo Genova, Maurizio Mazzucchelli, Luca Moreschi, and Davide Pederzoli.

Environmental performance of fuel cell buses: a Well-to-Wheel assessment of Greenhouse emissions

Cristina Carnevali[b], Adriana Del Borghi[a], Michela Gallo[a], Riccardo Genova[b], Maurizio Mazzucchelli[b], Luca Moreschi[a], and Davide Pederzoli[b,*]

The 4 accepted articles for conferences are:

- Proceedings of 2nd IEEE-International Energy Conference and Exhibition (EnergyCon2012), September 9-12, 2012 - Florence, Italy. "Fuel cell electric buses and perspectives: High V.LO-City Project" Authors: C.Carnevali , R. Genova , P. Jenné , M. Mazzucchelli ,M. Reijalt , G. Priano

- Proceedings of 1 conference Passengers Road Transport Systems.– January 30-31 2014, Rome, Italy. "Innovation, research and development in the LPT for road systems: European experiences and fuel cell buses". Authors: Cristina Carnevali, Riccardo Genova, Maurizio Mazzucchelli, Gabriele Priano

- Proceedings of IEEE International Electric Vehicle Conference – Florence (Italy) December 16-19 2014, "Testing and monitoring for FC buses fleets in the EU project HighVLO City". Authors: Cristina Carnevali, Riccardo Genova, Maurizio Mazzucchelli, Gabriele Priano

- Proceedings of 2nd. Conference Passengers Road Transport Systems – Rome (Italy),May 5-6 2016, "Innovation and technology in LPT, EU programs and the HighV.LO-City project". Authors: Cristina Carnevali, Riccardo Genova, Maurizio Mazzucchelli, Gabriele Priano

A2) List of all dissemination activities

No.	Type of activities	Main leader	Title	Date/Period	Place	Type of Audience	Size of Audience	Countries Addressed
1	Conferences	ACC + HyER	Mid-term conference: Aberdeen Hydrogen	22-25 April 2015	Aberdeen, UK	Policy makers	200	Various EU countries
2	Conferences	HyER + Groning	Project final conference	27/nov/17	Groningen, NL	Policy makers	40	Netherlands, Germany
3	Conferences	ACC	HyTrEc2 final conference	15/mei/15	Aberdeen, UK	Policy makers	150	UK + other countries
4	Presentations	HyER, Van Hoo	FCH-JU Programme Review Days 2019	27/nov/19	Brussels, BE	Scientific community	400+	All EU countries
5	Media briefings	San Remo	Launch of San Remo site	30/nov/18	San Remo, Italy	Medias	50	Italy
6	Presentations	HyER	Conference on the future of road transport	27/sep/19	Berlin, DE	Industry	70	Germany
7	Presentations	HyER	International Forum for Sustainable Mobilit	17/mei/19	Encontramento, PT	Policy Makers	150	Portugal
8	Presentations	ACC	Energy Cities Annual Conference	22-25 April 2015	Aberdeen, UK	Policy makers	200	Various EU countries
9	Press releases	HyER	Groningen site joins High V LO-City project	apr/17	Online	Policy Makers	500+	EU countries
10	Presentations	HyER	LowCVP workshop on buses	8/mrt/18	Glasgow, UK	Policy Makers	150	UK
11	Presentations	HyER	All Energy 2018	6/mei/18	Glasgow, UK	Industry	50	UK
12	Video	ACC	CNBC video - Aberdeen hydrogen	okt/17	Aberdeen, UK	Civil Society		UK, Europe
13	Press releases	HyER	PitPoint invests in Antwerp station	apr/17	Online	Policy Makers	500+	EU countries
14	Workshops	HyER	Time to move on? Advancing zero emission	jun/19	Brussels, BE	Policy Makers	70	EU countries
15	Web	PitPoint	Case study - Hydrogen Refuelling Station De	mrt/19	Online	Civil Society		EU countries
16	Press releases	HyER	Launch of San Remo site	nov/18	Online	Policy Makers		EU countries
17	Press releases	ACC	Aberdeen's pioneering hydrogen bus projec	jan/19	Online	Medias		UK
18	Exhibitions	HyER, WSN	Stand - Zero Emission Bus Conference 2018	27/nov/18	Cologne, DE	Policy Makers	200+	Germany, EU countries
19	Presentations	HyER	All Energy 2019 - SUMS	16/mei/19	Glasgow, UK	Industry	50	UK
20	Other	ACC	Aberdeen Hydrogen Festival - station visit +	1-4 October 2019	Aberdeen, UK	Industry	30+	UK
21	Articles published in	San Remo	La Stampa - Bus a idrogeno il primo viaggio	1/dec/18	Italy	Civil Society		Italy
22	Other	Qbuzz	Us of bus to transport Kind of the Netherlar	26/jun/19	Groningen, NL	Medias		Netherlands
23	Other	QBuzz	Dutch Prime Minister Mark Rutte - Visit to C	29/mrt/19	Groningen, NL	Medias		Netherlands
24	TV-Clips	QBuzz	Dutch channel NPO - Hydrogen programme	23/jan/19	Groningen, NL	Medias		Netherlands
25	Exhibitions	DeLijn	Use of bus - TechBoost!	28/mrt/19	Ghent, BE	Scientific community	20+	Belgium
26	Exhibitions	HyER, PitPoint	Ten-T Days 2016	jun/16	Rotterdam, NL	Policy Makers	200+	EU countries
27	Flyers	HyER	Project Newsletter	dec/17	Online	Policy makers	500+	EU countries
28	Flyers	HyER, PitPoint	End of project flyer	end of 2019	Printed flyer	Policy makers		EU countries
29	Flyers	HyER, PitPoint	Project flyer	beginning of 2017	Printed flyer	Policy makers	1000+	EU countries
30	Press releases	ACC	Hydrogen Transport Summit	5/feb/17	Online	Medias		UK

30	Press releases	ACC	Hydrogen Transport Summit	5/feb/17	Online	Medias		UK
31	Press releases	ACC	Hydrogen Transport Summit - aimed at bus	3/mrt/17	Online	Industry		UK
32	Articles published in	ACC	Aberdeen's hydrogen bus fleet to double as	17/mrt/17	Printed newspaper + online	Civil Society		UK
33	Presentations	HyER	GIANTLEAP Project Workshop, part of the V	12/dec/17	Belfort, FR	Industry	30+	France + EU
34	Presentations	HyER	European Fuel Cells Conference	14/dec/17	Naples, IT	Scientific community	30+	Italy + EU
35	Other	QBuzz	Commissioner Bulc visit of bus - Ten-T Days	26/apr/18	Ljubljana, Slovenia	Policy Makers		Slovenia + EU
36	Other	Qbuzz	Use of bus for launch of Colruyt refuelling s	2018	Brussels, BE	Policy Makers	30+	Belgium
37	Press releases	ACC	1 year of operation FC bus project	11/mrt/16	Online	Civil Society		UK
38	Press releases	HyER	Launch of the FCH Knowledge base	29/nov/16	Online	Policy Makers		EU countries
39	Other	De Lijn	Shuttle bus - opening of Zaventem station	22/apr/16	Brussels, BE	Policy Makers	50+	Belgium
40	Presentations	Van Hool	Annual Fuel Cell & Hydrogen Technical Conf	15/mrt/16	Birmingham, UK	Industry	100	UK
41	Presentations	DITEN	Convegno Sistema Gomma nel Trasporto Pa	5/mei/16	Roma, IT	Scientific community	50+	Italy
42	Presentations	HyER	World Hydrogen Energy Conference	13-16 June 2016	Zaragoza, ES	Scientific community	50+	Spain
43	Presentations	ACC	Euro Bus Forum	23/jun/16	Manchester, UK	Industry	50+	UK
44	Presentations	ACC	Scottish Hydrogen & Fuel Cell Association A	31/aug/16	St Andrews, UK	Industry	150+	UK
45	Presentations	ACC	Danish Hydrogen Fuel Cell Partnership even	sep/16	Copenhagen, DK	Policy makers	50+	Denmark
46	Presentations	Van Hool, WSN	WaterstofNet Congress	25/okt/16	Antwerp, BE	Policy makers	150+	Belgium
47	Presentations	WSN	Workshop on Hydrogen	8/nov/18	Vlissingen, NL	Policy makers	30+	Netherlands
48	Presentations	ACC, HyER	FCH-JU Stakeholder Forum	23/nov/16	Brussels, BE	Policy makers	300+	Belgium, EU countries
49	Presentations	ACC	International FCB Workshop	1/dec/16	London, UK	Policy makers	50+	UK, EU countries
50	Presentations	WSN	H2Net Congress	1/dec/16	Namur, BE	Policy makers	50+	Belgium
51	Presentations	WSN	Regio 2.0 event West Flanders	14/dec/16	Kortrijk, BE	Policy makers	50+	Belgium
52	Other	ACC	Use of bus: Doors Open Day, Aberdeen, Sep	sep/16	Aberdeen, UK	Civil Society	100+	UK
53	Other	ACC	Award- Low Carbon Champions Awards 20	2016	UK	Policy Makers		UK
54	Other	ACC	Scottish Public Service Awards 2016, Comm	2016	Scotland, UK	Policy makers		UK
55	Presentations	ACC	SHFCA North Atlantic Hydrogen Association	8/sep/15	Edinburgh, UK	Scientific community	50+	UK
56	Other	ACC	Various visits to refuelling station	2015-2019	Aberdeen, UK	Policy makers	200+	EU countries
57	Other	QBuzz	Various visits to refuelling station	2018-2019	Delfzjil, Netherlands	Policy makers	100+	EU countries
58	Workshops	HyER	Expert Workshop - High VLO City project	20/mei/16	Brussels, BE	Policy makers	20+	EU countries

Section B:

Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

TEMPLATE B1 : LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[13]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

No Applications for patents trademarks, registered designs have been done within the HighVLOCity-project

Part B2:

TEMPLATE B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND								
Type of exploitable foreground [14]	**Description of exploitable Foreground**	**Confidential Click on YES/NO**	**Foreseen embargo date dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable, commercial use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
	1. New superconductive Nb- Ti alloy			*MRI equipment*	*1. Medical* *2. Industrial inspection*	**2008** **2010**	*A materials patent is planned for 2006*	*Beneficiary X (owner)* *Beneficiary Y,* *Beneficiary Z, Poss. licensing to equipment manuf. ABC*

Not applicable

Annex : Report on societal implications

Replies to the following questions will assist the FCH JU and European Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
FCH JU Grant Agreement Number:	278192
Title of Project:	Cities speeding up the integration of hydrogen buses
Name and Title of Coordinator:	Geert van Hecke (MBA)

B Ethics		
1. Did you have ethicists or others with specific experience of ethical issues involved in the project?	O X	Yes No
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***	
INFORMED CONSENT		
• Did the project involve children?	**No**	
• Did the project involve patients or persons not able to give consent?	**No**	
• Did the project involve adult healthy volunteers?	**No**	
• Did the project involve Human Genetic Material?	**No**	
• Did the project involve Human biological samples?	**No**	
• Did the project involve Human data collection?	**No**	
RESEARCH ON HUMAN EMBRYO/FOETUS		
• Did the project involve Human Embryos?	**No**	
• Did the project involve Human Foetal Tissue / Cells?	**No**	
• Did the project involve Human Embryonic Stem Cells?	**No**	
PRIVACY		
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)	**No**	
• Did the project involve tracking the location or observation of people?	**No**	
RESEARCH ON ANIMALS		
• Did the project involve research on animals?	**No**	
• Were those animals transgenic small laboratory animals?	**No**	
• Were those animals transgenic farm animals?	**No**	
• Were those animals cloning farm animals?	**No**	
• Were those animals non-human primates?	**No**	
RESEARCH INVOLVING DEVELOPING COUNTRIES		
• Use of local resources (genetic, animal, plant etc)	**No**	

• Benefit to local community (capacity building ie access to healthcare, education etc)	**No**
DUAL USE	
• Research having potential military / terrorist application	**No**

C Workforce Statistics

3 Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	**Number of Women**	**Number of Men**
Scientific Coordinator		
Work package leader	2	3
Experienced researcher (i.e. PhD holders)	1	2
PhD Students		1
Other	6	18

4 How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	1
Of which, indicate the number of women:	0

D	Gender Aspects		
5	**Did you carry out specific Gender Equality Actions under the project ?**	○ X	Yes No

6 Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
X	Other:	**Not applicable**				

7 Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8 Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9 Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

X Yes- please specify — **The Fuelcellbuses.eu knowledge portal website**

○ No

F Interdisciplinarity

10 Which disciplines (see list below) are involved in your project?

X Main discipline[5]:

○ Associated discipline[11]: ○ Associated discipline[11]:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

X No, **not in this sense, citizens as in passengers on buses were.**

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project		
11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ X	Yes No

12 Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- X Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid	X X	Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	 X

13c If Yes, at which level?

- X Local / regional levels
- X National level
- X European level
- X International level

[5] Insert number from list below (Frascati Manual)

H	Use and dissemination	
14	How many Articles were published/accepted for publication in peer-reviewed journals?	
To how many of these is open access[6] provided?		
	How many of these are published in open access journals?	
	How many of these are published in open repositories?	
To how many of these is open access not provided?		
	Please check all applicable reasons for not providing open access:	

❑ publisher's licensing agreement would not permit publishing in a repository
❑ no suitable repository available
❑ no suitable open access journal available
❑ no funds available to publish in an open access journal
❑ lack of time and resources
❑ lack of information on open access
❑ other: ……………

15	**How many new patent applications ('priority filings') have been made?** *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		0
16	**Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).**	Trademark	0
		Registered design	0
		Other	0
17	**How many spin-off companies were created / are planned as a direct result of the project?**		0
	Indicate the approximate number of additional jobs in these companies:		0

18 Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	X	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify	❑	

19 For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs: *Difficult to estimate / not possible to quantify*	*The project involved 247,74 PMs, but actually about 262 PMs have been worked in the project, this calculates back to 21.8 (so almost 22 FTEs that have worked on the project.*

[6] Open Access is defined as free of charge access for anyone via the internet.

I Media and Communication to the general public

20 As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes X No

21 As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	X	Coverage in specialist press
X	Media briefing	X	Coverage in general (non-specialist) press
X	TV coverage / report	X	Coverage in national press
X	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		