Strategies for joint procurement of fuel cell buses

A study for the Fuel Cells and Hydrogen Joint Undertaking

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1 Executive summary

1.1 Context

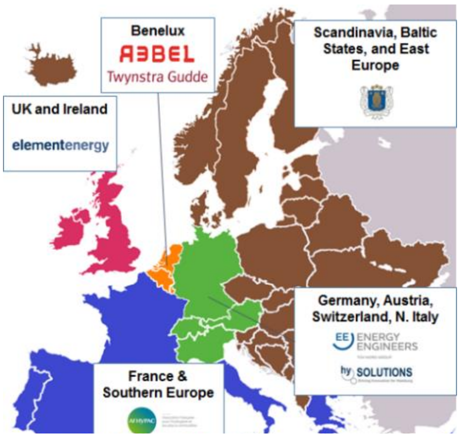
The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has supported a range of initiatives in recent years designed to develop hydrogen fuel cell buses to a point where they can fulfil their promise as a mainstream zero emission vehicle for public transport. Notable examples include:

Examples of fuel cell buses
Clockwise from top left: Hamburg, Cologne, London, and Aberdeen

- Real-world pre-commercial demonstration projects – since 2010, the FCH JU has committed over €118m to a series of fuel cell bus trials. The largest completed activity in this area to date is the CHIC project, which demonstrated 56 buses in eight cities between 2010 and 2016. CHIC showed that fuel cell buses can perform as like-for-like replacements for diesel vehicles in a wide range of operational environments and provided sufficient confidence in the technology for larger scale roll-out activities to be developed. The latest and most ambitious fuel cell bus deployment projects in Europe are now being delivered via the two phases of the JIVE initiative, which will lead to the introduction of close to 300 additional buses in 22 European cities / regions.

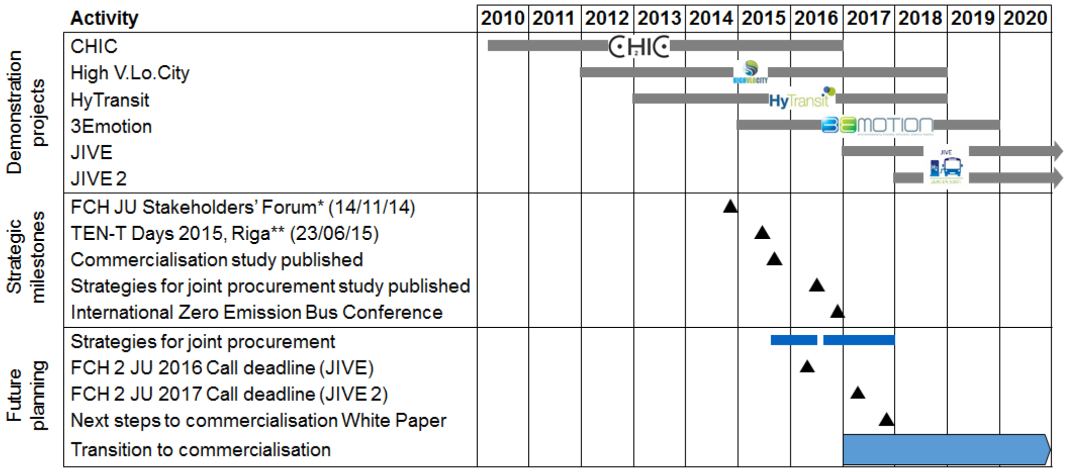
- A commercialisation process for fuel cell buses – the FCH JU funded a collaborative process involving industry representatives and potential customers for zero emission buses that led to the publication of the *Fuel Cell Bus Commercialisation Study* in 2015.[1] This report set out a vision for commercial deployment of hydrogen buses from the 2020s and laid the foundations for follow-on activities.
- The *cluster coordination* initiative – designed to aggregate demand for fuel cell buses and to develop approaches to joint procurement in five geographic clusters that will result in cost reductions via standardisation and economies of scale.

The timing of these activities, along with related strategic milestones for the fuel cell bus sector in Europe are shown below.



Geographic scope of the cluster coordinators in this study

1 www.fch.europa.eu/publications/fuel-cell-electric-buses-%E2%80%93-potential-sustainable-public-transport-europe.



* Plans for commercialisation of FC buses confirmed in joint letter from five European bus OEMs at the FCH JU's Stakeholders' Forum, Brussels (14/11/14).

** Declarations from innovative first buyers of five national clusters and from innovative producers signalling commitment to commercialising FC buses. TEN-T Days 2015, Riga (23/06/15).

Figure 1: Timing of major fuel cell bus demonstration projects and related studies

This report contains details of the work undertaken during the second phase of development of strategies for the joint procurement of fuel cell buses, a project that ran during 2016/17 and followed a similar initiative in 2015/16.[2]

1.2 Highlights and conclusions

Aggregating demands for fuel cell buses through *cluster coordination*

Building on the previous cluster coordination activities, the FCH JU tasked the cluster coordinators with securing the participation of at least 100 cities in the fuel cell bus roll-out planning activity with plans to eventually purchase 1,000 fuel cell buses and the related infrastructure. Since this project started in 2016, a related FCH JU-funded initiative on developing business cases for hydrogen technologies across a range of applications began.[3] Between these two studies, a total of around 90 different European cities / regions have been supported in understanding the business case of fuel cell bus deployment and across these locations a potential demand for over 1,500 vehicles has been identified.

[2] The final report from the first phase is available at: www.fch.europa.eu/publications/strategies-joint-procurement-fuel-cell-buses.

[3] www.fch.europa.eu/event/regions-and-cities-initiative-kick-event.

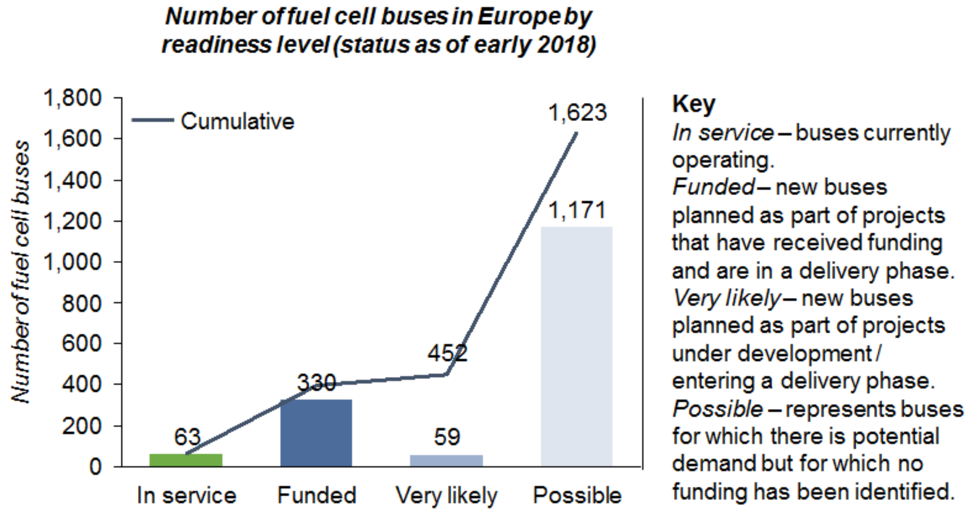


Figure 2: Number of fuel cell buses in service, planned for deployment ("Funded" / "Very likely", and potentially demanded ("Possible") across Europe

The figures presented in the graph above represent aggregated demands for fuel cell buses from cities / regions in all five of the geographic clusters across Europe. While plans to introduce buses in the "funded" and "very likely" categories are relatively well developed, the "possible" column indicates potential demands subject to further developments in the sector, which generally relates to either continued availability of subsidy at current levels, or (more likely) the need for further cost reductions of the vehicles and hydrogen fuel.

These figures are encouraging in the context of the outputs from the 2015 Fuel Cell Bus Commercialisation Study[4], which developed a roadmap based on delivering around 400 fuel cell buses to Europe by 2020 on the pathway to creating demands for many thousands of vehicles by the mid-2020s. The conclusions of this phase of demand aggregation suggest that the potential to create this level of demand for buses exists and hence the pathway to commercialisation is valid. However, the rate of practical progress in scaling up the demonstration fleets in the pre-2020 period has been slower than anticipated (see below). In addition, much work lies ahead in converting the sector from today's low volume economics to a price basis. The principal conclusions from this phase of cluster coordination activities include:

- **Strong in-principle demand** – the demand for fuel cell buses identified in the previous study remains strong and is increasing as a growing number of cities / regions seek to implement zero emission vehicle policies to tackle environmental issues. For example, there is growing momentum for fuel cell buses in France in the context of a high level of interest in battery electric buses, including commitments to introduce initial fleets of hydrogen buses in six cities. There is also increasing political support for a new special purpose vehicle to facilitate deployment of large fleets in the Benelux cluster, and fuel cell bus deployment plans in place in six cities across the Northern Europe cluster. In addition, new areas in Austria and a growing number of Italian cities have started to show an interest in fuel cell buses.
- **Delays in implementing deployments** – since the conclusion of the previous cluster coordination activity, the JIVE project was formally launched (January 2017), joint procurement exercises started in the UK and Germany, and plans were

[4] www.fch.europa.eu/publications/fuel-cell-electric-buses-%E2%80%93-potential-sustainable-public-transport-europe.

developed for further fuel cell bus projects (*JIVE 2*). However, the joint procurement exercises have taken longer to implement than originally envisaged, which means that most of the buses funded in the JIVE programme are yet to be ordered (as of early 2018).

- **A need to encourage participation of additional OEMs** – furthermore, the response from bus OEMs to the opportunity created by these initial tendering exercises was on the whole disappointing in the context of commitments made by industry in 2014[5] and feedback received during the early market engagement activities previously reported.[6] Given that the joint tenders sought many tens of buses in each cluster for deployment on a close to commercial basis, the industry response implies that many of the OEMs developing products in this area require further time for testing at small scales before committing to larger scale production. This suggests that further prototyping and demonstration activity is needed (for some OEMs) in parallel to deployment of tested products on a larger scale from those OEMs who are ready to commit to deployments at scale. As some of the manufacturers have announced that fuel cell buses will not be available before 2020, a continuous discussion and proof of a growing demand is needed to safeguard their active further development of vehicles until full technical maturity is reached.
- **Potential for substantial cost down from committed OEMs** – although the overall response from the European OEMs to the fuel cell bus tenders was slightly discouraging, some suppliers are responding to the opportunity with aggressive plans and have indicated the potential for significant price reductions under the right conditions, in particular scale and continuity of demand for standardised vehicles – see below. There is also evidence that some Asian bus OEMs are beginning to respond to this new market with attractively priced fuel cell buses being discussed in Europe. This mirrors recent developments in the battery electric bus market, and could lead to disruptively priced fuel cell bus products becoming available in the coming years.
- **Financing of buses is likely to increase in importance** – the cluster coordinators worked with cities to understand their financing needs for this first wave of deployments. In general, these heavily subsidised buses are funded using capital funding which is available within public sector balance sheets and there has been relatively little need for financial instruments to help support purchases of fleets of 5–20 buses. However, as the sector expands the fuel cell bus will need to be financed like most buses today, which implies leasing products for the buses and stations installed at the expense of the hydrogen suppliers.
- **The importance of cost-down** – while several hundred new vehicles may be introduced based on current economics (i.e. a bus price of c.€600k–€650k and European funding of c.€150k–€200k, leaving c.€450k to be covered by national and local sources), the next wave of deployment will require further cost reductions that allow suppliers to develop commercial offers acceptable to a wide range of customers. I.e. there is a need for a shift from project-based activities to a sustainable market in which fuel cell buses compete with diesel / other zero emission vehicles on a commercial basis. Evidence collected in this project suggests that given the right policy context, fuel cell buses could compete

[5] At the FCH JU's Stakeholder Forum in November 2014 five bus OEMs (Daimler Buses (EvoBus), MAN, Solaris, Van Hool, and VDL Bus & Coach) presented a joint letter signalling their intent to commercialise fuel cell buses.
[6] www.fch.europa.eu/publications/strategies-joint-procurement-fuel-cell-buses.

economically with battery electric buses and that pathways to removing the need for public subsidies for this sector exist.

- **A need for "affordable" hydrogen** – a repeated theme across the cities in the project is that the cost of hydrogen at small scale deployments is problematic. It is important that the hydrogen supply industry recognises that the bus industry will need low cost hydrogen to be competitive. A cost at or below the equivalent cost of taxed diesel is considered a minimum acceptable level (this suggests a price below €6/kg and ideally below €5/kg, depending on the assumption of the fuel economy of fuel cell vs diesel bus). There appears to be three broad approaches to achieving this:
    - **Scale of demand** – as explained in for example the NewBusFuel project, the amount of hydrogen consumed at a station has a major bearing on its cost. Pushing for larger scale fleet deployments at depots is required to achieve affordable hydrogen prices.
    - **Cost of energy** – low cost energy is required for hydrogen production, the best choice will be site specific and might include excess renewable electricity, biomass, spare hydrogen from existing production facilities or natural gas (ideally with carbon capture planned to be fitted to ensure a low CO_2 footprint). Regions should be encouraged to identify their lowest cost energy supplies as part of new hydrogen initiatives.
    - **Subsidy** – a number of countries have subsidies to support the cost of hydrogen. For example the UK has recently announced that "green" hydrogen will be included in the Renewable Transport Fuel Obligation, which will guarantee a subsidy per kilogram of hydrogen sold.

  There is an onus on hydrogen suppliers to develop and articulate bespoke business models which lead to low cost hydrogen for customers around Europe.

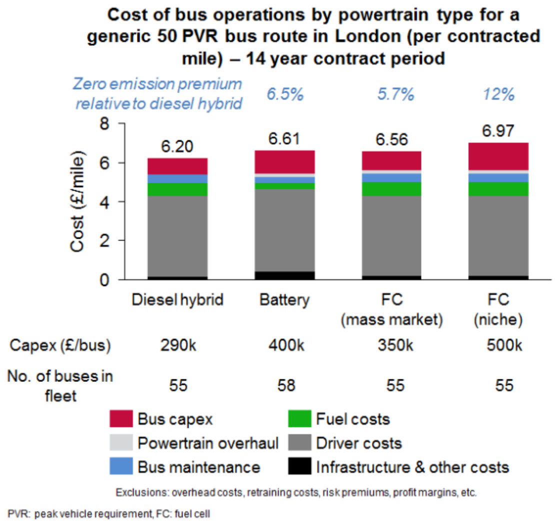
Planning further deployment of fuel cell buses beyond the subsidised phase

In addition to working with cities / regions to develop business cases for fuel cell bus deployment in the short term, the cluster coordinators examined the potential for larger scale uptake of this technology in Europe in an unsubsidised, commercial phase beyond 2020. This *planning beyond the subsidised phase* activity involved assessing the needs and constraints of the vehicle end users, and then working with bus OEMs and hydrogen suppliers to understand the conditions under which lower cost fuel cell bus solutions could be made available. The results of this exercise were encouraging and provided the basis for a White Paper on commercialisation of hydrogen fuel cell buses, which set out the following vision for the sector in Europe:

Fuel cell buses become a mainstream choice for public transport providers in cities and regions across Europe as they provide zero emission transport at a total cost of ownership equivalent to or below that of battery electric buses, with no operational compromises for operators or passengers compared to incumbent diesel technologies.

Realising this vision will require successful delivery of the funded demonstration projects now underway, specifically those within the JIVE initiative, which will provide additional evidence of the performance of fuel cell buses in larger fleets and prepare the market for larger scale deployment. It will also be necessary to overcome the remaining non-technical barriers such as relatively high fuel cell bus costs (capital and maintenance), costs of hydrogen, asset lifetimes / residual values, and cost of finance. Increasing the scale of deployment of fuel cell buses helps to address all these issues and will be central to the successful commercialisation of this sector.

Bus OEMs consulted in this study indicated that continuity and scale of demand will lead to significant price reductions, for example regular orders equivalent to around three buses per week per manufacturer will allow establishment of dedicated fuel cell bus production lines. The economies thus gained could lead to prices for 12m single deck fuel cell buses in the range €330k–€450k. These prices are €200k–€300k below the targets in the latest demonstration projects and could lead to fuel cell buses becoming the most cost-effective zero emission option in certain circumstances, as illustrated by an ownership cost analysis for a generic route in London (see graph).



The fact that to achieve meaningful price reductions bus OEMs need demand only in the low hundreds of vehicles per year gives cause for optimism, particularly as planned policy announcements by cities across Europe on a conservative basis are already sufficient to ensure a demand for over 5,000 buses per year by 2025. The fuel cell bus sector should advocate zero emission mandates for buses in areas with poor air quality, which are typically within large cities. Such policies will create a growing market for zero emission buses and signal to bus OEMs the need to prepare to scale up fuel cell bus manufacture.

However, zero emission mandates alone may not be sufficient for fuel cell buses to achieve the economies of scale and reach their full potential and a series of other measures may be considered by those seeking to develop this market, as discussed below.

1.3 Next steps

The cluster coordination exercise has led to formal joint procurement processes being run in two out of the five clusters to date. While progress towards placing firm orders for larger numbers of vehicles has been slower than anticipated, evidence from these tenders suggests that the joint procurement strategy is having the desired effect in terms of allowing suppliers to reduce production costs and hence offer more competitively priced buses than have been available in the past.

Furthermore, a number of suppliers have begun investigating options for bringing about more radical cost reductions with a view to offering fuel cell buses on a commercial basis from the early 2020s. The immediate next steps for this cluster coordination activity and the fuel cell bus sector in Europe as a whole include:

- **Deliver against existing commitments** – with the support of the FCH JU and numerous other national funders, plans are in place to introduce hundreds more fuel cell buses in selected cities / regions over the next few years. Turning these plans into hardware on the ground is a crucial next step to (a) provide additional evidence of the ability of the technology to operate with a high level of reliability on challenging routes across Europe, and (b) maintain momentum in this sector. The fuel cell sector has often citied hydrogen buses as offering great potential as a near-term commercial application of fuel cell technologies and to maintain credibility of these claims and continued buy-in from the various stakeholders it is imperative that ambitious plans are met by actions in practice.

- **Continue to plan larger scale roll-out for beyond 2020** – given the importance of continuity of demand for minimising fuel cell bus production costs, continued planning for further deployment in the post-2020 period is needed. There are positive signs in this area in terms of demand for vehicles (see above) and planning for post-2020 deployment has already begun. Two main delivery mechanisms are emerging:
    - A public sector led approach based on continued aggregation of demand amongst public authorities / transport operators, Here, further public sector subsidy interventions are likely to be required (albeit at lower intervention rates than seen in the past). The availability of these subsidies would help justify the aggregation of demand towards a next larger wave of fuel cell bus deployment across Europe, with the associated virtuous circle of increasing volume driving cost reductions. At a European level this would likely involve the Connecting Europe Facility fund and potential soft debt from the Clean Transport Facility at the European Investment Bank. This would also benefit from coordinated fuel cell bus initiatives which are implemented at a member state and local level.
    - A private sector led model through which industry players secure sufficient demand with limited formal coordination of the bus purchasers. Here, action is required from the bus and hydrogen fuelling industry to develop and then articulate a vision for the economics of fuel cell buses at a large scale. By presenting this to customers and then aggregating demand (which may involve some risk for the manufacturers), it becomes possible to envisage a private sector path to commercialisation.

  There is merit in seeking to progress with both options in parallel as these two approaches are not mutually exclusive. In practice, a hybrid of the two approaches is more likely than delivery via one or other of the options outlined above. There are potentially valuable synergies if the public sector and private sector work closely together. For example if the public sector intervention is targeted at the supply chain of the bus manufacturers to enable them to take a risk in moving to volume prices more rapidly, this may lead to lower intervention costs than subsidising generic fuel cell bus purchase.

- **Develop innovative financing and risk sharing mechanisms** – the latest feedback from bus suppliers and their customers suggests a desire to move away from “project” based thinking to frameworks that allow zero emission buses to be adopted in greater numbers. With further technology cost reductions, the focus will shift to developing novel financing approaches and business models that give appropriate risk sharing to allow public transport operators to scale up their fuel cell bus fleets (leases for buses and all-in hydrogen supply contracts). There are specific issues around the longevity of financing which need to be addressed. For buses, ensuring high residual values for the vehicles helps ensure manageable lease costs, whilst for the stations long-term contracts for hydrogen supply are needed to reduce the all-in cost of hydrogen when sold on a per kilogram basis. In both cases, the hydrogen bus sector benefits when longer than usual bus operation contracts are provided, ideally for periods in excess of ten years. These give certainty over future demand for the initial assets. If longer bus contracts cannot be provided, bus operators and transport authorities can help improve private sector loan terms by making policy commitments which imply a long life for both fuelling stations and zero emission buses. There may also be a role for public sector subsidised debt here to take additional risk on loan lengths for these projects, for example from the European Investment Bank's Clean Transport Facility.

- **Coordinated communications and outreach** – while awareness of hydrogen buses amongst public transport authorities / operators is increasing, familiarity with the technology across the bus sector remains relatively low. There is also some evidence of fuel cell buses being perceived as expensive and unreliable. The published price points for buses supported under the JIVE programme (standard single deck buses must be priced at or below €650k / €625k to be eligible for FCH JU funding in these projects) provide a useful benchmark, as do public statements from OEMs on potential future pricing (e.g. Solaris outlined stable quantities and continuity in the demand as the conditions under which a price of €450k for a fuel cell bus could be achieved at an event in September 2017). However, further statements from OEMs at major conferences / bus industry events on the potential commercial offers for fuel cell buses would help to increase awareness of and belief in this technology. The hydrogen bus sector needs to pay careful attention to communications in terms of managing expectations and avoiding hype, while increasing awareness of the development of fuel cell buses as a mainstream zero emission option from the early 2020s.

2 Introduction

2.1 Study context and aims

Following the completion of a study on *Strategies for Joint Procurement of Fuel Cell Buses* in June 2016, the FCH JU commissioned follow-on work to continue the coordination of procurement clusters and to plan the next wave of fuel cell bus deployment across Europe. The overarching vision behind this project was to support on-going efforts to reduce fuel cell bus costs to a level at which the need for subsidy is eliminated by stimulating demand for around 1,000 vehicles across Europe. To achieve this objective, the cluster coordinators sought to work with bus suppliers and customers to overcome the impasse of OEMs waiting for large orders before reducing costs and public transport authorities waiting for economic fuel cell buses before placing large orders.

The specific objectives of the cluster coordinators included:

- Support the on-going procurement activity for coordinated purchase of fuel cell buses in the UK, Germany / Northern Italy, France / Southern Europe, and Northern / Eastern Europe.
- Initiate new procurement exercises in further European regions and cities.
- Increase the number of cities participating in each cluster and support each partner in developing plans for fuel cell bus deployment.
- Develop strategies for financing many hundreds of buses beyond the current subsidised phase.

The geographic scope of each "cluster" along with the lead cluster coordinators is summarised below.

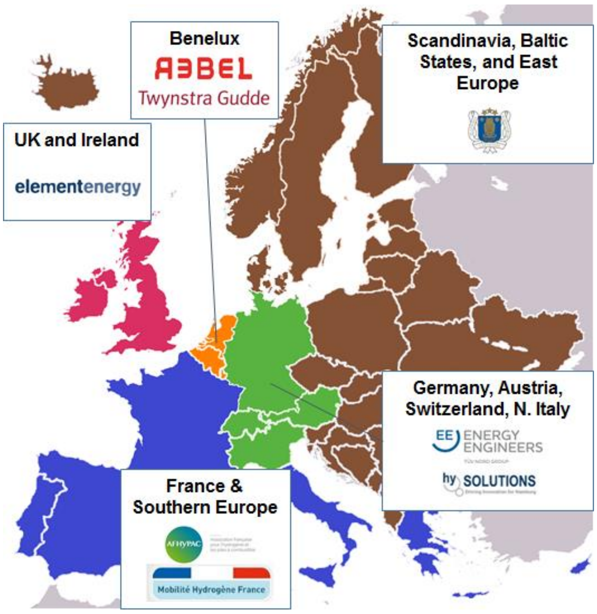


Figure 3: Cluster coordinators delivering the 2016/17 joint procurement strategy project

This is report summarises the work undertaken by the cluster coordinators from September 2016 to December 2017.

2.2 Europe's developing zero emission bus sector

2.2.1 Overview

Any effort to coordinate the introduction of zero emission vehicles at scale must recognise the broader context and priorities of the organisations funding and using the technology. This section therefore provides a brief overview of the zero emission bus sector in Europe, considering the key factors influencing the market from the demand side and the response from industry (the supply side).

2.2.2 Underlying factors driving demand for zero emission buses

Cities across Europe and beyond are facing common challenges, including:

- **Increasing urbanisation & congestion** – leading to growing demand for public transport services.
- **Environmental challenges** – poor air quality that causes harmful health impacts, and a requirement to reduce greenhouse gas emissions to combat climate change. While significant progress in reducing surface transport emissions has been made in recent years, for example with the introduction of Euro 6 standards, moving towards a zero emission, sustainable future will require increased uptake of fully zero emission vehicles.
- **Economic constraints** – providing affordable, reliable, high quality services with limited budgets.

These challenges are leading an increasing number of cities to focus on their public bus fleets as the early adopters of affordable and clean vehicle technologies. In this context, many of Europe's larger cities have set out ambitious policies designed to stimulate a transformational shift in the dominant powertrain technology used in their bus fleets. A selection of these policies is illustrated in the figure below, which implies that by the middle of the next decade many major European cities plan to procure only zero emission buses. These types of policies alter fundamentally the conditions for clean bus deployments: by effectively outlawing diesel vehicles, bus operators are forced to choose between ultra-low[7] / zero emission technologies. These policies alone imply a market for several thousand zero emission vehicles per year by the middle of the next decade.

[7] "Ultra-low emission vehicle" (ULEV) is a term used to describe any vehicle that uses low carbon technologies, emits less than a certain amount of CO_2/km from the tailpipe, and can operate in zero tailpipe emission mode for a given range. See www.smmt.co.uk/industry-topics/technology-innovation/ultra-low-emission-vehicles-ulevs/.

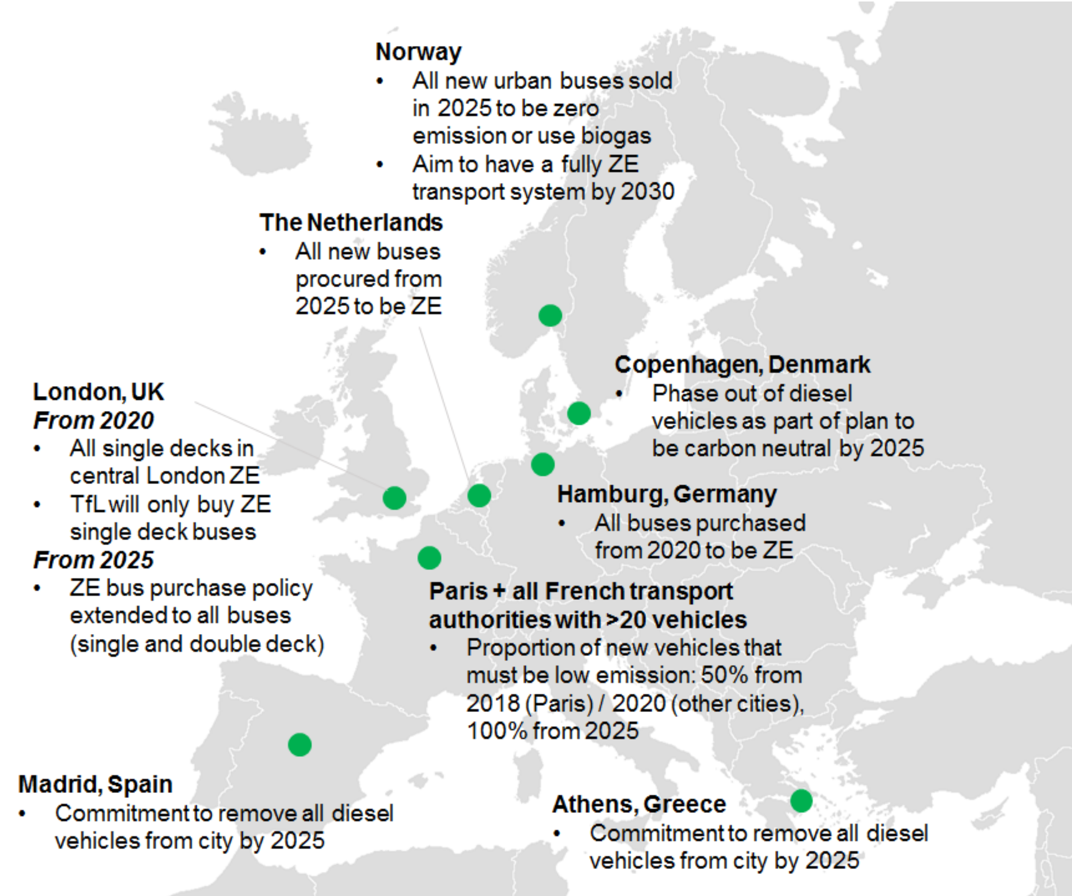


Figure 4: Overview of political commitments to accelerate uptake of zero emission (ZE) buses in selected cities / countries across Europe (TfL = Transport for London)

The level of interest in zero emission buses is demonstrated by the range of cities participating in the *Zero Emission Urban Bus System* (ZeEUS) project, a major EU-funded initiative that has been testing c.70 battery electric buses in ten “core” demonstration sites across nine countries since 2013/14. This project classifies cities as “core” (operating electric buses within ZeEUS), “observed” (operating electric buses outside of ZeEUS) and “user group” (cities interested in the technology and that are developing plans to introduce electric buses soon). As the map here shows, there is a significant amount of real-world demonstration activity in this area in cities across Europe.

Source: ZeEUS project: http://zeeus.eu/demonstrations-activities/demonstrations (accessed 05/12/17)

The ZeEUS project is due to conclude in April 2018 and has started to publish trial results. Further information is available from the project website: http://zeeus.eu/.

2.2.3 Industry response to demand for zero emission buses

Battery electric buses

Europe's battery electric bus market has grown substantially in recent years as the vehicle technology has been developed and tested through various real-world trials and is now being introduced into an increasing range of vehicles. The development of this sector is illustrated by the change in stock of ultra-low emission buses and coaches registered in the UK (one of the leading markets for zero emission buses in Europe) over the past seven years. Note that these figures include relate to "ultra-low emission buses", not only zero emission vehicles, but give an indication of the recent trends in this market.

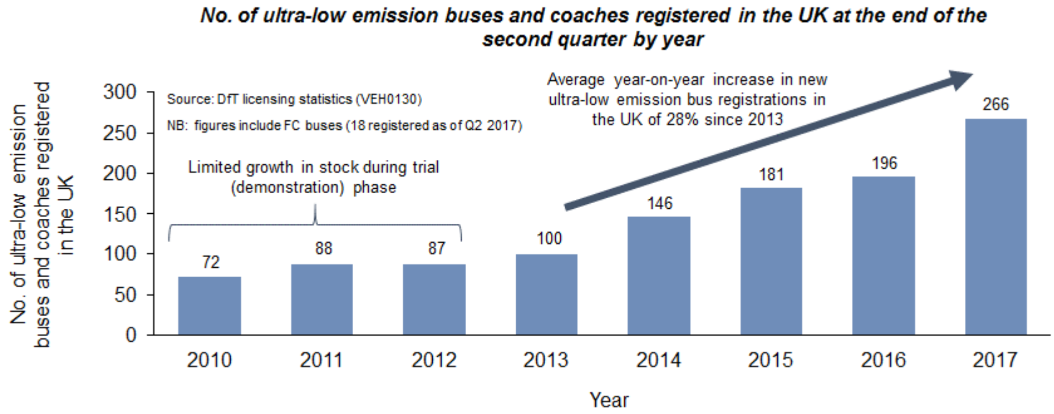
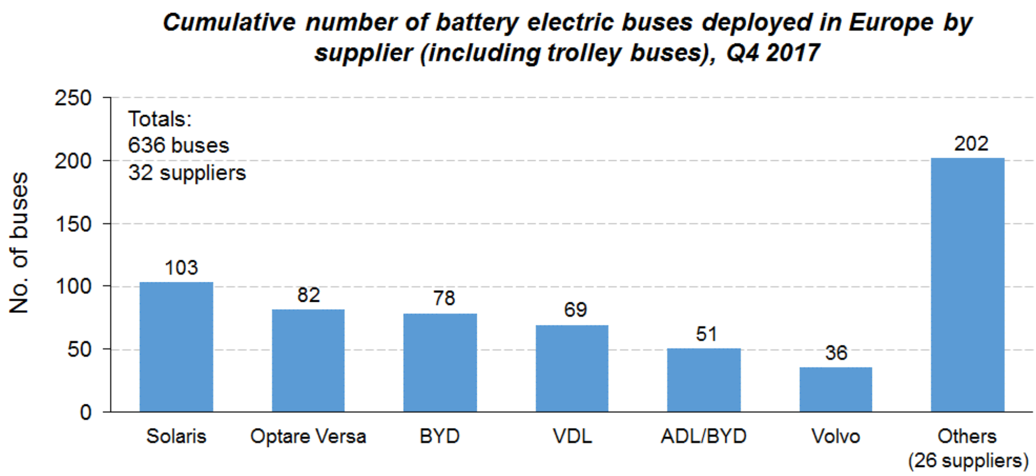


Figure 5: Number of ultra-low emission buses and coaches registered in the UK over time

Estimates of the total number of battery electric buses registered in Europe vary. For example, one source puts the total at 1,273 as of 2016[8], while other estimates suggest the number of battery electric buses in Europe is currently in the high hundreds.[9]



Source: based on European Alternative Fuels Observatory data (accessed December 2017): www.eafo.eu/vehicle-statistics/buses/cities

Figure 6: Total number of battery electric vehicles deployed in Europe by supplier (as of 2017)

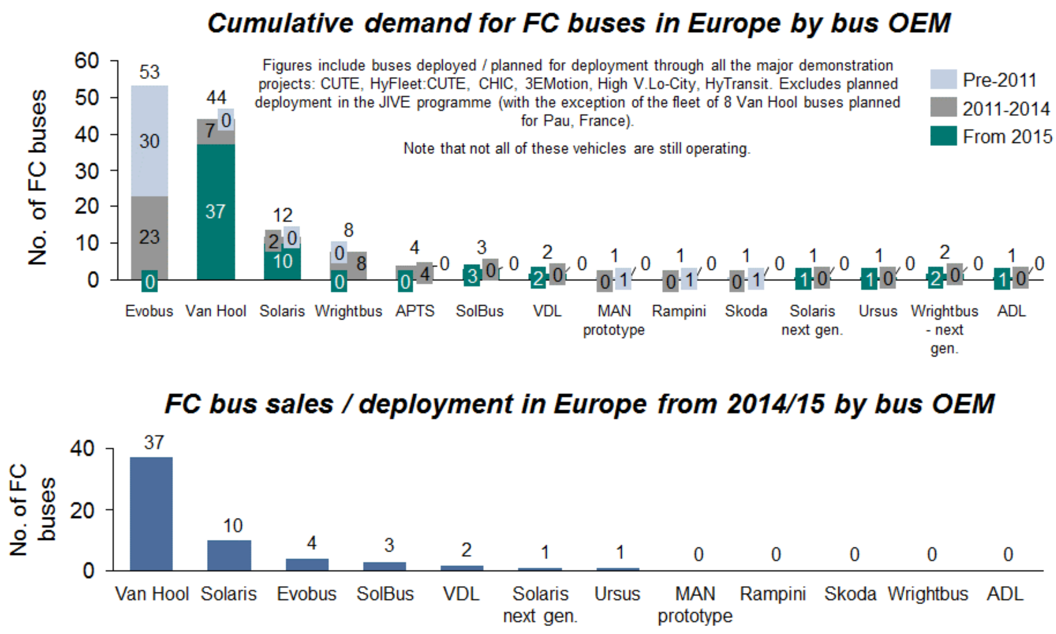
As indicated in the graph above, a large number of different bus suppliers are trialling battery electric buses and / or offering these types of vehicles for purchase on a commercial basis.

[8] *Global EV Outlook 2017*, International Energy Agency, p.28.
[9] European Alternative Fuels Observatory: www.eafo.eu/vehicle-statistics/buses/cities.

These figures suggest that the top six OEMs (by number of electric buses deployed) have been responsible for around two thirds of all battery electric buses in Europe to date, with the remaining vehicles coming from 26 other suppliers. According to these data, at least 32 different OEMs have deployed electric buses in Europe to date, a figure that is broadly consistent with a list of electric bus suppliers published as part of the ZeEUS project (and supported by the range of battery electric buses exhibited at BusWorld 2017 in Kortrijk).[10] It is clear that the majority of bus suppliers active in Europe are now offering or planning to offer battery electric buses in various configurations and that in the context described above (section 2.2.2), the sector is poised for significant growth over the coming years.

Fuel cell electric buses

Hydrogen fuel cell electric buses have been developed and trialled in Europe for at least fifteen years and in that time various OEMs have experimented with prototype vehicles or made more concerted efforts to test larger fleets in the field. As the graphs below show, historically Daimler (Evobus) has been a leader in this area, with over 50 buses used in previous demonstrations. In recent years (since 2015), Van Hool has dominated Europe's fuel cell bus market in terms of numbers of vehicles deployed / ordered. Practically all the vehicles represented by the figures below have been associated with some form of funded project as the fuel cell bus is not yet a commercially viable proposition (a fact that this study is seeking to change).



Source: based on data from http://fuelcellbuses.eu/category/demos-europe

Figure 7: Number of fuel cell buses sold / deployed in Europe by bus OEM

In comparison to the battery electric bus figures presented above, the following points are immediately apparent:

- The total number of buses deployed is significantly lower for the fuel cell option. As of late 2017, there are approximately 63 fuel cell buses in service in Europe (compared to >600 battery electric buses according to the figures above).

[10] *ZeEUS eBus report #2: An updated overview of electric buses in Europe* (October 2017). This report summarises the electric bus offers from 30 different vehicle suppliers.

- The number of European suppliers that have tested fleets of fuel cell buses (i.e. more than just one or two prototypes) is also low: only Evobus, Van Hool, Solaris, and Wrightbus have undertaken this type of real-world testing to date. This project has found evidence of other suppliers developing fuel cell buses (see section 8.2), but relative to the battery electric bus sector the number of highly active OEMs is low.

A key challenge of the fuel cell bus commercialisation effort relates to stimulating interest from more bus OEMs (as the sector requires a wider range of product offerings and increased competition) while simultaneously providing each OEM with sufficient order volumes to bring about the required cost reductions via economy of scale effects. One explanation for the low levels of fuel cell related activity amongst bus OEMs is the fact that engineering resources in many of these organisations are limited, especially in the smaller, privately owned companies. Bus suppliers have had to respond to changing requirements in the market over the past decade, for example with the introduction of increasingly stringent European emission standards, demands for hybrid vehicles (of various types), other alternative fuels, and fully zero emission buses. In this context, battery electric buses have emerged as the favoured zero emission technology for some OEMs and fuel cell buses are perceived as a few years behind in terms of commercial readiness, due to the current high cost of fuel cell drivetrain components and uncertainties around the fuelling infrastructure.

However, many in the industry believe that fully decarbonising the bus sector will require a range of powertrain solutions and that the technical characteristics of fuel cell buses make them particularly well suited to more demanding routes (e.g. high daily mileage, larger / heavier vehicles, hilly terrain etc.). Several OEMs are therefore continuing to develop / offer fuel cell buses and an increasing number are expected to enter this market before the end of the decade.

Looking beyond Europe, the fuel cell bus sector continues to develop elsewhere. For example, Toyota recently published further details of its SORA fuel cell bus, 100 of which will be deployed in time for the Olympic Games in Tokyo in 2020.[11]

Toyota's SORA fuel cell bus (source: Toyota)

Hyundai has also announced plans to develop a commercial fuel cell bus, with pre-production models from 2017 with a view to starting series production from around 2020.

Hyundai's fuel cell bus (source: Hyundai)

While the initial focus of these global OEMs will be on their domestic markets (Japan / South Korea), these developments are relevant for Europe by (a) increasing awareness of and momentum around fuel cell buses in general and (b) potentially leading to an increased range of competitively priced fuel cell vehicles in Europe – either via the Asian OEMs offering complete vehicles or through partnership approaches with European bus builders (similar to the ADL/BYD collaboration on electric buses).

[11] http://blog.toyota.co.uk/toyota-sora-bus-concept-explores-future-fuel-cell-technology.

There have also been relevant announcements relating to developments of fuel cell powered heavy duty vehicles in China during 2017. For example, two significant updates were published in June 2017 from Ballard and Hydrogenics:

- Ballard announced a follow-on deal with Broad-Ocean to support deployment of 400 fuel cell buses and trucks in China.[12] Broad-Ocean is a manufacturer of motors to power small and specialized electric machinery for electric vehicles, including buses and various other applications. This followed a statement in April 2017 that Ballard reached an agreement to supply Broad-Ocean with 200 *fuel cell engines*.[13]
- Hydrogenics announced an agreement to deliver 1,000 fuel cell units to *Blue-G New Energy Science and Technology Corporation* "Blue-G" (China), to be integrated into zero emission buses, with delivery scheduled over the period 2017–2020.[14]

These developments are relevant for the European market in the short term as the demand from these types of Chinese companies could lead to cost reductions of fuel cell stacks and other hydrogen components that could be beneficial to European customers. There is also the possibility of Chinese organisations offering fuel cell buses designed for the European market, either independently or in collaboration with European bus builders.

[12] http://ballard.com/about-ballard/newsroom/news-releases/2017/06/05/ballard-awarded-$18m-follow-on-deal-with-broad-ocean-to-support-deployment-of-400-buses-and-trucks-in-china.

[13] http://ballard.com/about-ballard/newsroom/news-releases/2017/04/06/ballard-inks-$11m-deal-with-broad-ocean-for-200-fuel-cell-engines-in-china-market.

[14] www.hydrogenics.com/2017/06/08/hydrogenics-signs-purchase-and-license-agreement-valued-at-over-50m-usd-for-1000-fuel-cell-bus-power-modules/.

3 Update on activities and plans by cluster

3.1 Introduction

Most of the work under the project was carried out by the individual cluster coordinators in each country, working with the various bus operators with an interest in hydrogen buses on a day-by-day basis. This section summarises these individual activities, which are then aggregated in subsequent chapters.

3.2 Benelux cluster

3.2.1 Context for fuel cell buses in Benelux

Since the year 2000, a situation of competitive bidding for public transport concessions for 8 to 10 years under the decentralized authority of the 12 Provinces in the Netherlands has been implemented. The public transport operators (PTOs) in the greater Amsterdam area (GVB), greater Rotterdam area (RET) and the greater the Hague area (HTM), are excluded from competitive bidding so far, and resort under the authority of Metropole regions (metropole region Rotterdam/The Hague and city region of Amsterdam).

In Belgium, three regional public transport organizations could be part of the further upscaling of hydrogen buses, under the authority of Flauders (De Lijn), Brussels (Stib) and Wallone (TEC). In Luxembourg these are RGTR and Ville Luxembourg.

Especially in the Netherlands, but also applicable in Belgium and Luxembourg, the decentralized situation in the public transport sector requires that private parties (PTOs) invest in new unproven technology, which is provided by public transport authorities (PTAs) through subsidies as a contribution towards the additional capital and operating expenditure involved.

3.2.2 Involvement in hydrogen bus projects

3Emotion

Under the 3Emotion project there will be six buses in operation in the Netherlands, two have been operated by RET in Rotterdam since September 2017 and four will be operated by Connexxion as per July 2018. Four of these buses are part of the Dutch hydrogen bus project. For both operations the buses will refuel at the HRS in Rhoon, operated by Air Liquide. For the buses of Connexxion, an upgrade of the Rhoon station is to increase the refuelling capacity. The buses for RET were produced by Van Hool, whereas the buses of Connexxion will be from VDL. The latter makes use of the innovative concept of an exchangeable hydrogen module at the rear of the bus. In this way, maintenance costs can be minimized. The bus itself is a standard electric bus and therefore only the hydrogen module needed to be developed. In terms of maintenance, the hydrogen module can be detached from the bus for repair / routine maintenance, and another module can be attached in order to continue operation.

High V.LO-City

Under the High V.LO-City project five hydrogen buses are operating in Antwerp. The buses refuel at the HRS operated by PitPoint. A further two hydrogen buses are in operation in the region of Groningen. The project is also part of the Dutch Hydrogen bus project. The buses will refuel at the new HRS in Delfzijl, operated by PitPoint.

H2Nodes

The two buses in Gelderland are also part of the H2-Nodes CEF Infrastructure project for hydrogen infrastructure in Latvia, Estonia and the Netherlands.

Dutch hydrogen bus project

In 2013 a subsidized programme for a pilot with two hydrogen buses per project was started by the Dutch Ministry of Infrastructure and Waterstaat. Five regions joined the project with a total of ten buses nationwide. These regions are: South-Holland, Groningen, Gelderland, North-Brabant and the City of Rotterdam. Four out of five projects are combined with a European subsidized programme.

Involvement in JIVE

There are no regions in the Benelux cluster within the JIVE project. The pilots with hydrogen buses in the Netherlands were not in operation when this project was formed and therefore the transport authorities and transport operators chose to gain experience with hydrogen buses before starting demonstrations projects. De Lijn chose not to join the JIVE project due to the pilot experiences with hydrogen buses.

Involvement in JIVE 2

Five regions in the Benelux Cluster joined this pan-European demonstration project. The best project proposals were from the regions South-Holland, North-Brabant and Groningen and therefore joined the consortium as full members. The regions Utrecht with Qbuzz and Wallonia with TEC were on the reserve list. In a later stage, the region of Utrecht withdrew as a reserve region from the project

3.2.3 Involvement with parties

Cities / regions / bus operators

Intensive collaboration among the provinces of Groningen, South-Holland and North Brabant in 2017 resulted in a collaborative agreement of signing the Grant Agreement for the JIVE 2 project in December 2017. In order for the provinces to do so, guarantees and securities from involved PTOs and cities were put in place. Although there are still some uncertainties in the business case since definite purchase and maintenance prices for the buses and a hydrogen price are not yet secured, PTAs and PTOs agreed upon further collaboration within JIVE 2. Per region the following parties are involved:

Groningen

In Groningen there is the advantage of a greenfield situation where a new concession starts at the end of 2019. In November 2017 the tender for the concession was published in which the obligation is included to operate 20 hydrogen buses, provided that a positive business case can be reached.

North-Brabant

In the beginning of 2017 two PTOs were possibly designated for operating the ten hydrogen buses: Hermes (part of Transdev Group) in the Eindhoven area and Arriva in the Breda area. Over time, Hermes showed less interest in operating the hydrogen buses since the operating scheme and local context was better suited for full battery electric buses. In addition, Hermes gains experience with hydrogen buses within the 3Emotion project and potentially within JIVE 2 in the PZH site. On the other hand, the city of Breda was very keen on having hydrogen buses in their city and Arriva is keen to gain experience in this area.

Moreover, for the supply of hydrogen, there is an opportunity to develop a combined hydrogen station for buses and garbage trucks, which will be subsidized with the European INTERREG programme and the Dutch DKTI subsidy arrangement. In this way a competitive hydrogen price is to be realized.

On senior level the province of North Brabant, the city of Breda, Arriva (PTO) and PitPoint (hydrogen supplier) agreed upon developing the integral project of buses and garbage trucks combined. Since the hydrogen buses will operate within an existing concession, the contract between the PTA and PTO needs to be revised. The renegotiations will take place in Q2/Q3 2018.

South-Holland

In South Holland, the PTO Connexxion is the contract holder of the current concession. They are responsible for the purchase and deployment (July 2018) of four hydrogen buses within the 3Emotion project and are keen to expand their fleet of hydrogen buses since the routes in the HWGO concession have long distances and a high average speed. For the HRS there are three options: 1) expand the current station in Rhoon, 2) build a new HRS next to the bus depot in Heinenoord or 3) establish a new HRS on the island of Goeree Overflakkee. The local government on the island of Goeree Overfalkkee prefers the latter solution since they have an ambition to make the island self-sustaining in terms of energy. Hydrogen can then act as storage for excess wind energy from off-shore wind parks and as an energy source for the buses.

Engagement with industry

In the year 2017 many meetings took place with infrastructure providers, hydrogen providers and bus OEMs. These meetings will be formalised in the context of the JIVE 2 project through a market consultation in February – April 2018.

Multiple dissemination activities have also taken place in collaboration with industry parties. Such as:

Netherlands

- Contact through the PT-working group of the Dutch National Hydrogen Platform with both public and private parties (such as hydrogen and infrastructure providers). Meetings with the National Hydrogen Platform were held every 1.5 months. One of the topics most discussed was an integrated approach between the realisation of hydrogen tanking facilities on public grounds and the upscaling of fuel cell bus fleets.
- In September 2017 the Dutch ministries of Infrastructure and Environment and the Ministry of Economic Affairs (responsible for energy) started to work on a roadmap for hydrogen in the Netherlands. The fuel cell bus strategy is part of this roadmap. In 2018, further arrangements have to be made to continue these meetings and workshops.
- The cluster coordinators have held approximately monthly calls for extensive discussions on the political ambition and financial possibilities. Also, the current experiences with building a consortium for hydrogen pilots with 2–4 buses have been reviewed.

Belgium

- Due to malfunctions in the operation of the hydrogen buses and discussions in the consortium the regional public transport operator De Lijn, has indicated that they currently have no appetite to participate in an upscaling strategy for hydrogen buses.

- The Wallonia Region has expressed its interest by issuing a letter of intent written by the responsible Minister of Transport Mr Di Antonio to the FCH JU on 28th September 2016. The ambition is 20 buses, however to date no written commitment has been received by the regional public transport operator Tec. Recently there have been talks with both De Lijn and TEC on different matters.

Luxembourg

- Although an extensive visit has been made to the Luxembourg Ministry of Transport to explain the purpose and opportunities for Luxembourg of the FCH JU 2017 call, the Ministry decided not to participate in the current upscaling and is focussing on battery electric (hybrid) solutions in close cooperation with Volvo.

Others

- In June 2017 the Benelux cluster coordinators were present at a joint-procurement strategy meeting in Dusseldorf with the Northern Europe and French cluster coordinators to establish a knowledge transfer on the latest German hydrogen bus tender.

3.2.4 Analysis of options for a joint procurement

The aim of the cluster management activities in the Benelux region is to develop a strategy for joint procurement of hydrogen buses, aiming to standardise the specifications of buses and lower costs by a high number of buses in procurement batches. Through multiple workshops and bilateral meetings with PTOs and PTAs in the Netherlands, Belgium and Luxembourg, policymakers from the Dutch Ministry for Infrastructure and Environment and the Dutch Investment Agency, a preferred strategy for joint procurement has been agreed.

Discussions with PTAs and PTOs concluded that a traditional approach where the operator would fully finance the investment and assume the full risk, might not be the optimal way to organise the procurement and operation of the buses. In that case each operator has to procure their buses on their own, which is believed to be more expensive in comparison to ordering 50 buses at once. As a result, it has been suggested to implement the project via a designated Project Company (‘SPV’) which will be responsible for delivering the buses including maintenance and/or the hydrogen refuelling infrastructure. In the first half of 2018 three forms of joint-procurement are being explored in detail:

1. Joint procurement for purchase of buses by operators
2. Joint procurement for purchase of buses organised by authorities
3. Designated Project Company; a Special Purpose Vehicle

It is expected that in early Q3 2018 a final decision will be made on which of the options will be used to procure the buses. The purchase of the buses will take place in December 2018.

1. Joint Procurement by operators

Experiences in the Netherlands with two or three competing operators jointly purchase buses – a core component of their business – has not led to many successful projects and is therefore not a good option to go forward. This option is not likely to be feasible since the operators are in a highly competitive market where collaboration is rare.

2. Joint Procurement by authorities

Purchasing hydrogen buses through cooperating public transport authorities is more likely to be a feasible option. Experiences with these collaborations are more common. This form of joint procurement is part of the approach in the Netherlands. The first step is to investigate a more intensive collaboration with certain benefits (see below) and this is a fall back scenario.

3. Special Purpose Vehicle

If the operator is not making the investment in the buses, the bus-as-a-service can be supplied through a separate entity. We refer to this entity as a Special Purpose Vehicle (SPV). The SPV acts as a vehicle for the investment, maintenance and management of the buses. The SPV can be set up by several shareholders, some of whom may play a role in the delivery of the project or service.

Aim of the SPV

The aim of the SPV is to procure jointly 50 buses for the Benelux market, against a fixed lease fee to the PTOs. This SPV structure makes it possible to procure this high number of buses in one tender, to mitigate the risks appropriately, and to negotiate the best price with multiple suppliers. Also, the SPV will distribute the buses to different PTAs, if these PTAs are unable for whatever reason to deploy these buses for a short period to realise an acceptable business case. The SPV will be able to distribute knowledge in a transparent way, and so will contribute to a realistic risk assessment of deploying fuel cell buses. This will enhance demand for the buses and lower the prices.

Of course bus-as-a-service can also be supplied by companies rather than a separate SPV. However, we see the following benefits of using an SPV in the provision of the buses:

- Ring fencing of investment, cash flows and especially liabilities;
- Clear contract structure with managed rights and liabilities, that is, risks and upsides can be transparently structured and allocated between different parties;
- Investors can enter joint ventures with technology suppliers or operators in a single entity;
- Corporate investors can sell the business without complex rearranging of contracts. This would allow the transport authority to act as a launching investor that may exit when the service takes off commercially making it attractive to outside investors.

In discussions with involved parties, two models can be distinguished, namely:

- Publicly owned SPV model;
- Private investor owned SPV model.

Each model assumes that an SPV would be set up to deliver the project/service.

1) Publicly owned SPV model

This model assumes that the three provinces will set up an SPV, specifically for investing in the buses (capital costs and maintenance costs), and delivering them to the operators. Similarly, the SPV will sign a purchase contract with an OEM, together with a follow up service contract. Under this implementation model, the SPV would charge its users a service fee, if applicable, including the hydrogen consumption charge.

2) Private investor owned SPV model

This model assumes that an SPV is set up by third party investor(s) who will purchase and maintain the buses. It is possible, for example, for an existing lease company or OEM to participate in the SPV. Alternatively, both services can be contracted in a similar manner as in the other two models. Under this implementation model, the SPV would charge its users a service fee, including the hydrogen consumption charge. Compared to the other models, a private investor owned SPV could attract external financiers, interested to provide debt or equity to the SPV.

The table below summarises the main characteristics of each model giving an overview of the main differences in roles assumed by the potential stakeholders involved.

Table 1 Overview of the implementation models

	Publicly owned SPV model	Private investor owned SPV model
Transport Authority	• Lead party / investor • Manage daily operations of the SPV • Could offer incentives to operators	• Can provide guarantees for hydrogen offtake • Could offer incentives to operators • Can provide capex (upfront) subsidy/financing
Transport operator	• Operates the buses • Enter into a hydrogen offtake agreement	• Operates the buses • Enter into a hydrogen offtake agreement • Convert of the fleet
OEM	• Designs, builds and services the buses based on the contract with operators	• Assume (partial) ownership • Designs, builds and services the buses based on the contract with operators
Hydrogen supplier	• Supplies hydrogen to the operator	• Assume partial ownership • Supplies hydrogen to the operator
Financiers	• Provide debt finance to the SPV (by BNG, bank of Dutch municipalities)	• Provide equity/ debt finance to the SPV

While each of the models are presented as individual options, it should be noted that each may be altered, depending on the responsibilities to be assumed by the SPV and individual risk appetite of each shareholder.

The SPV is developed for the Dutch market due to representatives in JIVE 2, but applicable for Belgium and Luxembourg situation in upcoming years.

The aim of the SPV is to deploy 50 buses within the JIVE 2 project in the Benelux cluster. The SPV has the consent of the Dutch Ministry of Infrastructure and Environment and the involved regional PTAs. The SPV is endorsed also by the PTOs. Additional finance is under negotiation between the Ministry of Infrastructure and Environment and PTAs, based on the business case of the SPV.

The SPV will offer the option to finance the complete fuel cell bus, with a focus on the riskiest parts in the deployment of the fuel cell buses i.e.:

- The fuel cells and battery pack.
- Maintenance of the electric driveline, fuel cell and battery pack.

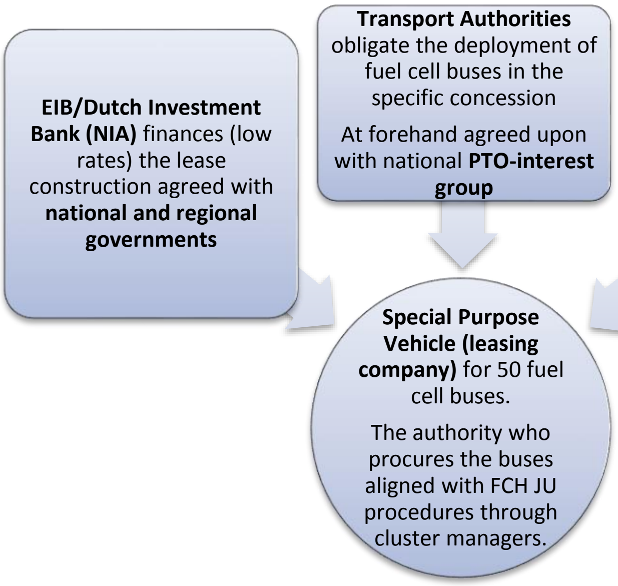


Figure 8: Overview of the SPV and main responsibilities of the involved parties

The roles and responsibilities of the parties involved in the SPV are as follows:

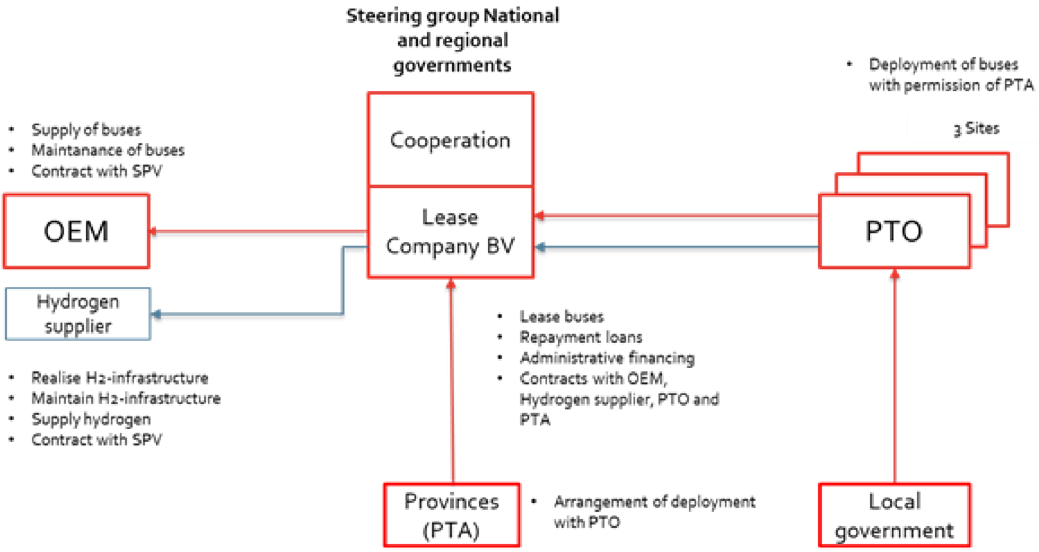


Figure 9: Diagram showing dependencies between parties

Expansion

The joint procurement exercise is currently focussed on the JIVE 2 demonstration project with three Dutch Regions. However future demonstration projects in the Benelux and other European regions can join this exercise.

- Luxembourg and Belgium are not excluded from participating in the SPV.
- The SPV is planned to be fully operational following confirmation of all necessary funding, which includes an FCH JU grant from the 2017 Call (JIVE 2).
- If, for any reason, the SPV is not realised in time, the committed regions will procure buses themselves through a joint procurement by authorities and / or in close collaboration with European cluster procurement.

Planning and specifications for joint procurement

In the year 2017 progress was made on the regional and national business case, the joint procurement strategy and engagement with operators. On 20 December 2017 the Dutch Ministry of Infrastructure and Waterstaat and three regions made a positive decision for the further implementation of a joint procurement strategy. The financing from the FCH JU, national Government and regional bodies is in place.

Actions in 2018:

A. Joint Procurement
   1. The first step is to formalise the informal discussion with market parties through a formal market consultation to confirm the current business case, reconfirm the market appetite and verify the specifications. This will take place in March and April 2018.
   2. A final draft of the specification for **50 standardised, uniform and identical FC buses** will then be finalised in close alignment with the bus suppliers and transport operators. This will be finalised in June 2018.
   3. Set up the tender procedure with the aim to have the framework in place in September 2018.

   The result is a confirmation of realistic prices in the business case supported by market parties, agreement on the bus specifications and tender documents to start the formal tender procedure.

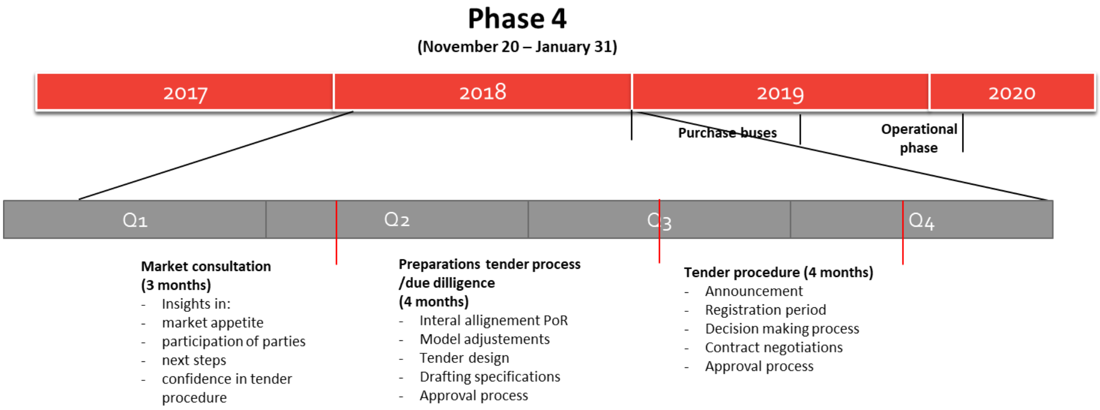
B. Establish the Special Purpose Vehicle
   1. The aim is to establish the SPV. If due to risks this is not an option, the fall-back scenario is the purchase of 50 identical fuel cell buses through a joint procurement by authorities.
   2. Organisation of the administrative ownerships of the SPV.
   3. The final step is to establish the collaboration between ministry and provinces in a consortium agreement.

   The result is an established SPV including governance and a consortium agreement between public and private parties. This step is due to be completed in September 2018.

C. Financial
   1. Further detail the business case for the fuel cell buses, hydrogen infrastructure, hydrogen supply and financing by public entities.
   2. Conduct a continuous detailed risk assessment.
   3. Obtain finalised financing by public entities.
   4. Explore future additional opex subsidies.

   This step is due to be completed in September 2018.

The formal purchase of the buses will take place at the end of 2018. Delivery of the buses and start of operation is planned for late 2019 / early 2020.



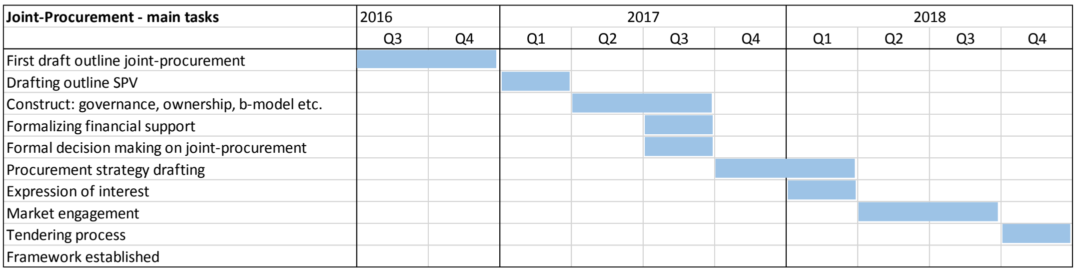
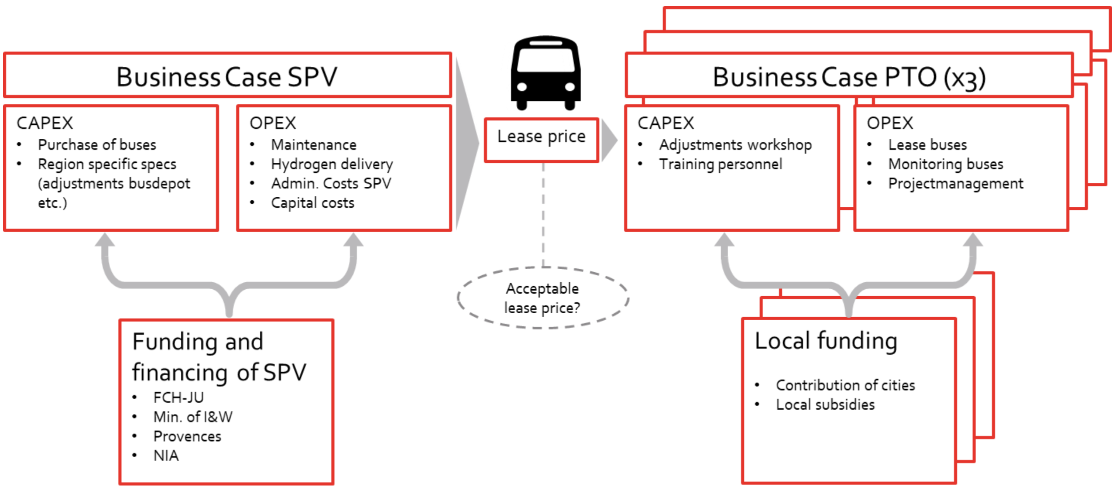


Figure 10: Gantt chart for the joint procurement activities in the Benelux cluster

Business case

A business case assessment of the SPV is conducted for the three regions Groningen, South-Holland and North-Brabant. A tool in an Excel model format captures the technical, financial and environmental factors in one place but still maintains flexibility and overview of all data. Conceptually the model looks like the figure below.



Based on experiences within pilot projects, information gained by OEMs, fuel cell manufacturers and PTOs, a set of input assumptions is agreed for the business case. In Q1 2018 a market consultation is planned in which the assumptions for the business case will be double checked and refined. Uncertainties are highest for the purchase and maintenance price of the buses and the hydrogen price.

The main cost drivers in the business case are:

1. Investment costs of the vehicle with the investment costs of the fuel cell as a specific point of attention.
2. Additional costs due to lower availability of hydrogen buses.
3. Maintenance costs of the vehicle, in particular the maintenance costs of the fuel cell per kilometre.
4. Cost of the hydrogen per kilogram.
5. Consumption of hydrogen (kg / km) and associated range of vehicles.
6. Number of kilometres to be driven including possible extra kilometres due to changes in the operation compared to diesel buses.
7. Additional deployment of personnel as a result of changes in the operation compared to diesel buses.

The total costs of deploying the hydrogen buses is a combination of the above factors. All these factors must be considered in conjunction with one another in order to make statements about the costs of using hydrogen buses in comparison with diesel and / or battery electric buses. The business case model takes into account all these parameters and converts them into a lease price per bus per month.

Capital expenditure

Based on the current figures a total investment of approximately € 30m. is needed to purchase the hydrogen buses. These capital expenditures are partly covered by the following funds:

- FCH-JU: € 7,4m
- Provinces: € 3,75m
- Min. of I&W: €3,75m

In order to purchase the hydrogen buses, in addition to the three subsidy flows, financing for an amount of around € 15 million is necessary (depending on the definite prices). For the financing of the project, discussions were held with the Netherlands Investment Agency (NIA). The NIA helps local and regional authorities, public-private partnerships and companies with access to finance, especially in the risky phases where the market is not yet fully established. NIA contributes to the elaboration of the business case, through the financing structure (guarantee, or zero rate lending to the provinces) and the co-determination of the risks. In 2018, a thorough risk analysis and allocation will be made in cooperation with the NIA and in agreement with the provinces on the basis of which the NIA can provide a loan at the lowest possible interest rate.

An alternative to financing the project is direct financing by the three provinces involved. At a zero rate, these funds can be made available and are repaid from lease income. Discussions with the treasury departments from the three provinces are on-going to further investigate the possibilities for financing from the provinces. This point is part of the agenda during the decision making in mid-2018.

Operational expenditure

The maintenance costs of hydrogen buses have a high impact on the operational costs of the business case. An increase in the maintenance price of € 0.10 / km leads to an increase in the lease price of approximately € 11,000 per bus per year for a mileage of 90,000 km per year. This amounts to € 6.6 million for the total business case of 50 buses for a term of twelve years. The maintenance costs partly depend on the average speed at which the buses run; the higher the average speed, the lower the maintenance costs per kilometer. The choice in the route where the hydrogen buses are used is therefore important for an optimal business case. Furthermore, the maintenance costs are composed of three parts:

1. Maintenance costs of the body of the bus; these are fairly certain, since there is a lot of experience with the maintenance of diesel and electric buses.
2. Fuel cell maintenance costs; these costs are still uncertain.
3. Periodic preventive maintenance on the hydrogen module; these costs are expected to have a limited share in the total maintenance price of a hydrogen bus.

The price level of maintenance costs issued in informal discussions with suppliers is around € 0.45 / km. Through exploratory talks with market parties and a formal market consultation that will be performed in Q1 2018, an increasingly clear picture of maintenance costs is to be generated, with costs expected to fall to a level of between € 0.30 / km and € 0.40 / km. Tendering 50 identical buses ensures a more efficient and cost-effective maintenance strategy which lowers the costs. In addition, defects or malfunctions in one bus can be prevented by experience in the other buses.

A second important factor in the operational costs is the hydrogen price. An increase in the hydrogen price of € 1 / kg leads to an increase of the lease price of approximately € 7,500 per bus per year with a mileage of 90,000 km per year. On the total business case for a term of 12 years, this amounts to € 4.5 million. The investment costs of the hydrogen infrastructure are not part of the business case, since these are covered in the hydrogen price. The owner of the hydrogen refuelling station recoups the investment in infrastructure through the sale of hydrogen. In order reduce the hydrogen price, a purchase guarantee of hydrogen is important. Based on experiences in other (small-scale) projects, it is expected that with a sufficient purchase guarantee (10–20 fuel cell buses for twelve years) a price of € 5 / kg is feasible. As with the buses, the SPV creates market forces by procuring hydrogen (infrastructure) and putting a tender on the market in order to get the best price. Due to region specific circumstances, three separate tenders for hydrogen might be the preferred option.

Interim concluding results from the business case

Based on assumptions on prices, the contribution of the FCH JU, national and regional funds, and low cost finance of the investment of the buses, a lease price is calculated. In the table below, the main assumptions in the business case and the resulting lease price per region is given. It has to be noted that the assumptions used are still subject to change, and therefore the final lease prices may differ from the ones in the table below. A final business case can be calculated when the tender for the delivery of the buses (and hydrogen) is answered and definite prices are known.

	Bus price (€)	Hydrogen price	Maintenance price	Mileage (km/bus/y)	Lease price (€/bus/y)
Groningen	625.000	€ 6,5 / kg	€ 0,34 / km	88.000	€ 120.000
South-Holland	625.000	€ 5 / kg	€ 0,30 / km	97.000 km	€ 105.000

North-Brabant	625.000	€ 5 / kg	€ 0,40 / km	66.000 km	€ 97.000

Note: these are interim results and no firm conclusions can be drawn from these figures.

3.2.5 Overview of the Benelux FC bus projects

Table 2: Overview of fuel cell buses deployed / planned in the Benelux region

	European projects	Dutch projects	Number of buses	Type of buses	Bus supplier	HRS/H_2 supply
Antwerp	High Velocity	/	5	12	De Lijn	PitPoint
Gelderland	H2Nodes		1	12m	SOL	TBC
Gelderland	/	H2-pilots	4	12m	Ursus	TBC
Groningen Drenthe	HighVelocity	H2-pilots	2	12m	VanHool	AkzoNobel /PitPoint
Groningen Drenthe	JIVE 2	#name	20	12m	TBC	TBC
North-Brabant	/	H2-pilots	2	18m	VDL	Waterstofnet /PitPoint
North-Brabant	JIVE 2	#name	10	12m	TBC	TBC
Rotterdam	3Emotion	H2-pilots	2	12m	VanHool	AirLiquide
South-Holland	3Emotion	H2-pilots	4	12m	VDL	AirLiquide
South-Holland	JIVE 2	#name	20	12m	TBC	TBC

- Rotterdam: currently deploying two hydrogen buses through a national programme and 3Emotion and expressed interest for future deployment in the long term. There is no appetite for 2017 due to high investments and little experience with the current hydrogen bus operation.
- South-Holland: deploying four hydrogen buses in July 2018 through the Dutch Hydrogen Bus project programme and 3Emotion and plans to deploy 20 hydrogen buses in the JIVE 2 project.
- North-Brabant: currently deploying two hydrogen articulated buses through the Dutch Hydrogen Bus project and will deploy 10 hydrogen buses in the JIVE 2 project.
- Gelderland: currently deploying one hydrogen bus and possible four hydrogen buses through the Dutch Hydrogen Bus project. Expressed interested in a long-term deployment. There was no appetite to join the JIVE 2 project due to a complicated situation regarding the possible take-off guarantee for the buses and hydrogen station.
- Groningen: currently deploying two hydrogen buses through the Dutch Hydrogen Bus project and High V.LO-City and will deploy 20 hydrogen buses in the JIVE 2 project.
- Wallonia: expressed interest in long-term deployment of 20 hydrogen buses with ten hydrogen buses in the first phase. Wallonia is one of the reserve cities that could take on funding in JIVE 2 should the opportunity arise.

- Luxembourg: expressed interest in future deployment in the long term. There was no appetite to join the JIVE 2 project due to high investments and no experience with hydrogen bus operations.
- Utrecht: originally expressed interest in long-term deployment of 20 hydrogen buses and joined the JIVE 2 funding application as a reserve city. However, the political focus has shifted towards electric buses, mainly due to the perceived high costs of fuel cell buses (as presented by the transport operator).
- Antwerp: currently deploying five hydrogen buses through High V.LO-City. There was no appetite to join the JIVE 2 project due to malfunctions in the operation of the hydrogen buses and discussions in the consortium.

These figures are based on the results of local feasibility work on the potential for fuel cell bus deployment undertaken in the cluster. Any deployment of fuel cell buses is contingent upon receiving suitable offers for bus and hydrogen supply through the procurement processes and securing all the necessary funding.

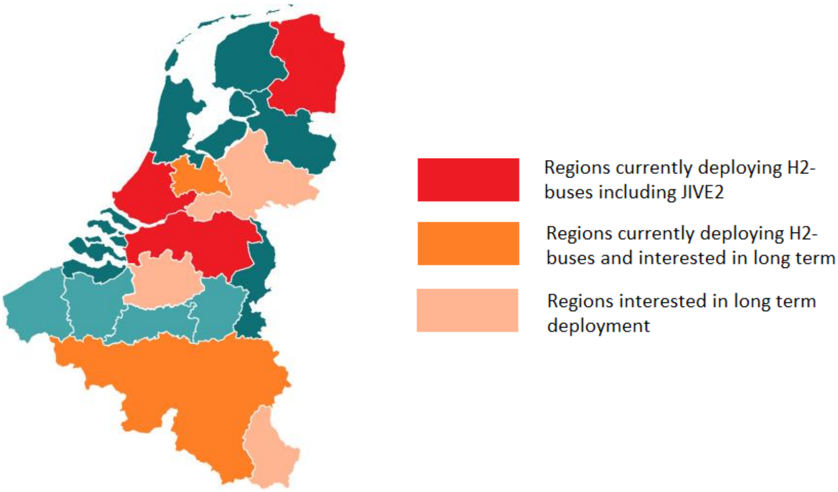


Figure 11: Geographic locations of regions in the Benelux cluster interested in deploying fuel cell buses

Further details of the context in which demand for fuel cell buses exists in the Benelux with firm deployment plans are given in the following table.

Region	Population (approx.)[15]	Bus fleet size	Current primary operator(s)	No. of bus HRS
Groningen	583,581 (2017)	c.300	Qbuzz (until 2019)	One (Delfzijl) + planned
North-Brabant (3 concessions)	2,512,531 (2017)	c. 180, 165, 200	Hermes, Arriva	One (Helmond) + planned
South-Holland (3 concessions)	3,650,222 (2017)	c. 82, 125, 225	Connexxion	One (Rhoon) + planned (Oude Tonge)

Utrecht (3 concessions)	1,284,504 (2016)	c.300, 181, 58	Qbuzz, Syntus	None
Wallonia	3,576,325 (2014)	c.600	TEC	None

3.2.6 Next steps

A. Further meetings between market parties and government bodies are required to continue sharing information with public and private parties regarding the possibilities for hydrogen buses in the Benelux region.
B. Discussing the possibilities for upscaling in 2019 with other sites in the Benelux.
C. Realising the SPV to make the joint procurement possible.
D. Discussing the possibilities for the future commercialisation of the fuel cell bus market in the Benelux area with OEMs (VDL, Van Hool and Solaris) as part of the joint procurement strategy.
E. Investigate funding options for buses not included in JIVE 2.
F. Build coalitions for future hydrogen projects.
G. Share knowledge in a safety study for hydrogen roll-out in the Benelux conducted by the hydrogen platform.

3.3 French cluster

3.3.1 Context for fuel cell buses in France

During the second half of 2016, the Hydrogen Mobilité France consortium (which is the mobility arm of AFHYPAC, the French Association for Hydrogen and Fuel Cells) was commissioned to advance the French fuel cell bus strategy and development activities. At that time, no hydrogen buses had been tested or deployed in France, and there was no official announcement with regards to a concrete deployment plan (except from Cherbourg, as discussed below). From the list of cities issued by the previous business development activities, only three agglomerations appeared to be concretely involved in the project – Cherbourg, Artois-Gohelle, and Pau – while all the other cities were far from initiating any concrete projects. Cherbourg, initially engaged in the 3Emotion project, eventually dropped out. Artois-Gohelle continued its development plan and at the time of writing is engaging in public tenders. Pau started a public tender open to all types of powertrains in 2017, eventually choosing to use fuel cell buses in August 2017.

In July 2015, the French government published a new law defining the targets assigned to French cities for replacing existing fleets of diesel buses (‘*Loi sur la transition énergétique*’), and in January 2017 specific decrees were published to define the term “low emission buses”.[16] Two categories of low emission buses were defined:

- Group 1: 100% electric (including fuel cell buses), and gas combustion if a fraction of the gas is biogas (20% in 2015, 30% after 2020).
- Group 2: hybrid buses (diesel-electric), or gas combustion, and biofuels, if 50% of the fuel is guaranteed to originate from renewable sources.

In order to determine eligible technologies for new buses, two types of zones were defined based on population density and exposure to atmospheric pollution. Paris and the 22 surrounding agglomerations, as well as the centre of other agglomerations containing over

[16] *Décret n° 2017-23 du 11 janvier 2017 pris pour l’application de l’article L. 224-8 du code de l’environnement définissant les critères caractérisant les autobus et autocars à faibles émissions.*

250,000 inhabitants will only be allowed to deploy buses from Group 1. Agglomerations under a PPA ('*Plan de Protection de l'Atmosphère*' – Atmosphere Protection Plan) are also covered, with 39 PPAs signed to date, representing half of the French population. All other agglomerations must deploy Group 2 buses at the very least, although they are free to deploy lower emission Group 1 buses.

The renewal objectives are phased to progressively achieve a 100% target by 2025: from the 1st of January 2020, 50% of all new vehicles used in public transport will have to be low emission, with this share increasing to 100% from the 1st of January 2025. This applies to all public transport bodies in France that operate more than 20 buses/coaches. The only exception is Paris, where the 50% rule will be applied earlier, from the 1st January 2018.

It is anticipated that the effort required for the French cities to comply with this law will cost them a total of circa 3.8 billion euros.[17] Discussions with French cities show that they are struggling with these aggressive goals, especially when it comes to zero emission solutions such as battery or fuel cell electric vehicles. Indeed, they are finding it difficult to procure low emission buses that would be able to cover all routes and comply with all operational constraints. In addition, cities do not have funding plans in place for the replacement of buses with more expensive models.

The fuel cell bus solution is generally unknown in France, and batteries are seen as the only mature solution for zero emission mobility. The main bus operator in France, RATP (Paris and surrounding agglomerations) has announced ambitious plans for banning diesel buses from their 4,600 bus fleet in 8 years: 80% will be battery electric buses and 20% will be biogas. Other French cities tend to consider battery electric buses as the only viable solution on the market, and major bus manufacturers (including French ones such as Bolloré) actively promote batteries and natural gas buses (or biogas buses), while dismissing the fuel cell option.

3.3.2 Approach in the French cluster

Initiating and catalysing the deployment of hydrogen buses in France requires different types of stakeholders to get involved in the process. These various types of stakeholders can broadly be grouped within two categories:

1. Technology providers, i.e. industrial stakeholders providing hydrogen refuelling stations, hydrogen buses, etc.
2. Bus owners and / or operators, i.e. cities, regions, public transport operators, along with public transport associations, etc.

The Hydrogen Mobility France (H2MF) consortium comprises most of the main French industrial entities involved (or planning to get involved) in the hydrogen mobility sector. The consortium was therefore strategically positioned to define a common strategy for the deployment of FC buses as well as to reach out to bus owners and / or operators in French cities and regions.

Industrial stakeholders – creation of a FC Bus Working Group

When AFHYPAC was selected by the FCH JU as the coordinator of the French Hydrogen Bus cluster in 2016, the H2MF consortium created a dedicated working group focused on the hydrogen bus sector. This dedicated group's objective has been to engage with all relevant stakeholders, support the development of FC bus projects, and define / put in place a plan which would allow for the joint procurement of fuel cell buses in France. The

[17] www.mobilicites.com/011-4381-3-8-milliards-d-euros-la-lourde-facture-des-bus-propres.html

stakeholders from the H2MF consortium that stepped forward to be part of this FC Bus Working Group are presented in the figure below.

Figure 12: Hydrogen Mobility France members involved in the FC Bus Working Group

It should be noted that this group is comprised of some vehicle manufacturers (Toyota, Safra, and to a certain extent, LUTB[18] which is a 'competitivity cluster' that counts Iveco as one of its members), five hydrogen refuelling station providers and operators (Air Liquide, ArevaH2Gen, Engie / GNVERT, McPhy, ITM power) and one FC manufacturer (SymbioFCell).

The main activities conducted by this working group are summarised in the paragraphs below.

Involvement with cities / regions / bus operators

Early in this project, the lack of French documentation on FC buses was identified as a barrier to the spread of knowledge about the technology. Therefore, the working group created two documents in French to support conversations with French stakeholders. The first document is a short, high level presentation that has been used during initial meetings with the cities and bus operators. It gives an overview of the advantages of the technology, its technical readiness, French industrials involved in the sector and the benefits FC technology might provide to a city / region. The second document is more detailed and could be shared at the end of these meetings or communicated to people who expressed an interest in learning more about the technology. This second documents gives more details about the subjects already mentioned and presents existing FC deployments in Europe, recent technology developments, FC buses currently on the market, an overview of the business case, a retrospective on achieved cost reductions, the concept of joint procurement, and the objectives of the JIVE project.

[18] In November 2017, LUTB was renamed CARA, European Cluster for Mobility Solutions.

Figure 13: Covers of the French FC bus documentations (short presentation – left; long version – right)

In terms of involvement with specific FC bus projects, the strategy of the French cluster has been to start by focusing all efforts on acquiring first references in France, which was identified as necessary in order to create some first “success stories” and be able to initiate a joint procurement process. Therefore, the cluster coordinators focused the business development effort on the most promising prospects.

During the preparation of a response to the FCH JU Annual Work Programme 2017, the role of AFHYPAC was key in terms of communicating this funding opportunity to the cities and identifying projects that were sufficiently advanced to apply for it. Seiya Consulting and Element Energy (coordinators of the Working Group on behalf of AFHYPAC) engaged in dialogue with each of the cities which were interested in applying and helped project owners to articulate their projects in such a way that they could prove the projects were advanced enough to be strong components of this European project. Initially, the possibility of integrating six French cities or regions was considered, from these, the three most advanced projects were brought forward and are now part of the JIVE 2 consortium. The three cities are Auxerre, Pau and Toulouse, with five buses per city. This was the first time that French cities had taken part in a European level hydrogen bus project right from the start.

In parallel, the French cluster helped the cities of Pau and Versailles to apply for the 3Emotion project and replace Cherbourg and Antwerp after they dropped out. Both applications were successful, for three buses in Pau (in addition to the five JIVE 2 buses) and two buses in Versailles Grand Parc.

In addition to the meetings arranged with these four cities (Auxerre, Pau, Toulouse, Versailles), in-person meetings were organised with Lyon, Grenoble, Montpellier and Alès to discuss potential hydrogen bus projects. In order to build up a larger French network it was decided to invite all cities interested in the hydrogen solution to a full-day workshop dedicated to FC buses.

The objectives of the day were to:

- Present the value proposition of the H2MF Bus Cluster
- Motivate national transport associations and legacy procurement groups
- Gather inputs to elaborate the French strategy
- Create a community of interest to facilitate exchanges
- Recruit towns for the joint procurement and elaborate the plan
- Discuss and debate the issues and solutions

The workshop took place in Lyon on 24th May 2017, with the agenda presented below.

Time	Agenda
9:30	Welcome
10:00	Introduction H2MF and CNR • Presentation of the French cluster (Fabio Ferrari, H2MF) • Hydrogen as part of the energy system (Frédéric Storck, CNR)
10:20	FC buses in Europe • CHIC, on-going projects (Sabrine Skiker, Hydrogen Europe)
10:35	JIVE, Joint Procurements, UK case (Ben Madden, Element Energy)
11:00	Presentation of two projects in France • Toulouse (Thomas Bourgue, Engie Cofely) • Auxerre (Emmanuel Schuddinck, Justy)
11:30	Risks and security, state of the art and training (ENSOP)
11:45	Discussion / Q&A

Time	Agenda
12:05	Site visit: HRS
12:30	*Lunch*
14:00	**Workshop 1:** Requirements for FC buses
14:45	**Workshop 2:** The FC bus solution
15:30	*Coffee break*
15:45	**Workshop 3:** Potential structure for a Joint Procurement
16:00	Conclusion & Next steps

Figure 14: Agenda of the FC bus workshop in Lyon, France, 24th May 2017

This workshop benefitted from a high level of attendance and was given very positive feedback in terms of quality of the presentations and discussions. While the initial objective was to have 40 participants, the final list of people registered for the event counted 50 participants and there were very few “no shows”. Targeted participants included: representatives of interested cities (unions and operators), public transport associations (GART, AGIR, CATP…), private global operators (TransDev, Keolis, CarPostal), institutions and regional authorities, members of the hydrogen ecosystem, manufacturers, bus OEMs, etc. Half of the participants were city representatives, global or local operators, regional territories, and national associations for public transport and joint procurement. The other half were from the hydrogen ecosystem, energy players, bus manufacturers, and competitive clusters. Participants in this workshop are presented in the table below.

Cities / Regions	Industry stakeholders	Transport associations / entities
• Auvergne-Rhône-Alpes (Conseil Régional, DREAL) • Auxerre (Eolbus – Justy) • Clermont-Ferrand (SMTC-AC) • Lyon (Grand Lyon, Sytral) • Orléans (Loire Orléans Eco) • Paris (Ville de Paris, RATP) • Rouen (Métropole Rouen Normandie) • Toulouse • Artois-Gohelle Lens-Béthune (Assystem) • Montélimar (Courriers Rhodaniens, CEA)	• Air Liquide • CNR • Engie • GNVert • ITM Power • McPhy • Michelin	• GART • CATP • AGIR **Pôle de Compétitivité** • LUTB • PVF • Tenerrdis
Bus operators	**Vehicle manufacturers**	**Others**
• CarPostal • Keolis • TransDev	• CNHI • Safra • SymbioFCell	• CEA • Hydrogene Europe • Element Energy • ENSOP, SDMIS 69 • Seiya Consulting

Feedback from the participants confirmed that the session was very welcome and that cities have a strong need for information. Most cities, as well as the global bus operators, really are « hydrogen beginners » and require a deeper understanding of the hydrogen solution, especially in terms of operational details, not only regarding the buses and their performances, but also with regards to the necessary energy system, depot upgrades, maintenance, and fleet management.

This workshop was the first of its kind in France and initiated the creation of a group of cities / regions / bus operators, interested in the FC bus sector. One of the main next steps for the French FC bus cluster (described next) will be to keep the momentum created during this workshop by organising regular meetings with these stakeholders to share information, gather data, answer questions and help with de development of new projects.

Analysis of options for a joint procurement

The main objective of the French FC Bus Working Group (in addition to supporting bus operators on the individual FC bus deployment projects) is to define and initiate the joint procurement of FC buses in France.

To that end and because the rollout of FC buses is at a very early stage in France, joint procurements currently on-going in the UK and in Germany were presented as a first step and discussed in detail within the Working Group. This discussion benefitted from Element Energy's expertise gained from the UK's joint procurement, and detailed information could be shared about the German joint procurement thanks to a meeting organised by the German cluster on the subject, in Düsseldorf.

The Working Group identified the need to better their understanding of the bus market in France, in terms of numbers, types of vehicles and tendering processes, in addition to identifying the main stakeholders. In this vein, an initial analysis was conducted by the coordinators. The figure below presents an excerpt from this analysis (number of buses in France by location and sales by bus manufacturers in 2016), which will be completed in the next few months with inputs from members of the Working Group, especially those from bus manufacturers.

Number of buses by region – 1st January 2017

Régions	Number of buses	%
Île-de-France	11601	40%
Auvergne-Rhône-Alpes	3202	11%
Provence-Alpes-Côte d'Azur	2375	8%
Hauts-de-France	1978	7%
Nouvelle-Aquitaine	1737	6%
Occitanie	1642	6%
Grand Est	1601	6%
Bretagne	1065	4%
Normandie	1011	4%
Pays de la Loire	1004	3%
Bourgogne-Franche-Comté	745	3%
Centre-Val de Loire	699	2%
Corse	61	0%
TOTAL	**28721**	**100%**

40% buses are in Île-de-France

Départements	Number of buses	%
Essonne	932	8%
Hauts-de-Seine	844	7%
Paris	**6842**	**59%**
Seine-et-Marne	928	8%
Seine-Saint-Denis	385	3%
Val-de-Marne	5	0%
Val-d'Oise	649	6%
Yvelines	1016	9%
Total Île-de-France	**11601**	**100%**

More than 50% of buses in Île-de-France are in Paris

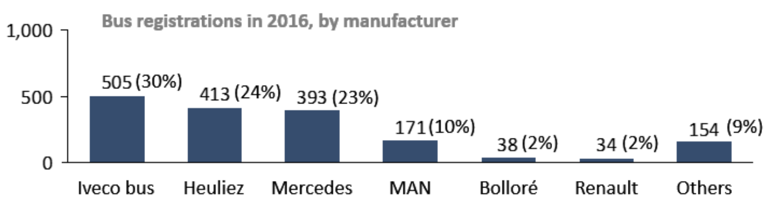


Figure 15: Excerpt from the analysis of the French bus market

The main stakeholders whose inputs might be required to organise a joint procurement process were identified and contacted. Although others may be identified in the near future and invited to join the process, the main ones are expected to be the transport associations GART, AGIR and CATP.

In order to help small – and medium – sized cities with bus procurement (larger cities usually handle these processes themselves), the CATP ('*Centrale d'Achat du Transport Public*' / '*Public Transport Central Purchasing Body*') has established legal frameworks for referencing and negotiating bus pricing with manufacturers. They were therefore identified as a good option for taking the lead on a joint procurement process. They were contacted, and an initial meeting was organised with their CEO and Commercial Director in May 2017 to present the French FC Bus Cluster and discuss the opportunity of FC bus joint procurement. During this first contact with the CATP, they expressed an interest in FC bus technology, highlighted the fact that they had received requests for FC buses in the past, and expressed an interest in getting involved in discussions on the French cluster joint procurement project. In order to kick-start this process, they participated in the FC Bus Workshop in Lyon (24th May 2017) and presented their actions and showed their willingness to procure low emission buses.

Following these first steps, the agenda proposed for the next meeting with the CATP included discussions on the exact type(s) of FC bus model(s) that they could add to their catalogue, their tendering processes, envisaged timelines and the best way for the CATP and the French cluster to cooperate on the subject. Unfortunately, the CATP was unable to find the time for a meeting in the summer or autumn of 2017, and at the end of 2017 a date for the meeting still needed to be confirmed. However, in early January 2017, the CATP reiterated expressing their interest in FC buses and a meeting could be scheduled, for early February 2018. Although having the CATP lead the FC bus joint procurement process is the preferred option, it is expected to take additional time to confirm whether this is a viable procurement route.

In order to account for the risk that the CATP finally decides not to engage with FC buses, other options are being investigated. The French Bus Working Group is engaging discussions with UGAP ('*Union des groupements d'achats publics*', specialised in all types of joint procurements for the public sector) and the main French transport operators (in particular Keolis and Transdev). In late November 2017, Keolis decided to join the consortium and the FC Bus Working Group. In January 2018, Transdev also decided to join the consortium and the FC Bus Working Group. The option of a joint procurement led by one city on behalf of others, similar to the UK and German models, is also being investigated. The lead city could be one already involved in fuel cell bus procurements (for example the JIVE 2 cities of Auxerre, Pau or Toulouse), or another city with significant bus needs. At the time of writing, a new phase of communication towards cities and discussion with city representatives is being organised to investigate this option. A new communication document about FC buses, in French, was produced by the FC Bus Working Group, in December 2017. In early 2018, one of the main objectives of the Working Group is to disseminate this document efficiently. On the 6th January 2018, it had already been sent to approximatively 150 contacts by the Working group coordinators and Com'Publics, and the Working Group members started to also disseminate the document.

Engagement with bus manufacturers & cost modelling

In parallel to the discussions and actions put in place for local FC bus deployment projects and French joint procurement strategies, the working group initiated a discussion on potential FC bus offers from French manufacturers. This discussion is facilitated by the presence of bus manufacturers within the working group, in particular Iveco – via LUTB, LUTB being a member of H2MF, and Iveco a member of LUTB[19] – and Safra.

Safra – Businova model

[19] In November 2017, LUTB was renamed CARA, European Cluster for Mobility Solutions.

Safra is a bus manufacturer based in the Toulouse area. They already have experience in manufacturing low emission buses and they have expressed a strong interest in FC buses. At the time of writing they are about to start working on the first prototype of their FC bus model before entering the production phase. They are also working closely with HyPort project partners (in Toulouse – as described further below) who are in the process of five fuel cell buses funded by the JIVE2 project. Wanting to participate to the FC Bus Working Group, Safra joined the H2MF consortium in 2017.

Safra – manufacturing facility

In November 2017, the cluster coordinators organised a bilateral meeting with Safra in their headquarters and manufacturing facility in Albi (near Toulouse) to discuss their technology offer. They currently have the capacity to work on 5 buses in parallel and produce up to 10 buses a year, which could be increased to 30 to 50 buses a year from as early as 2019-2020. Their potential to reach the JIVE 2 project capital costs and the long-term cost reduction targets announced recently by other manufacturers was also discussed, and Safra's feedback was that these costs are achievable subject to sufficient order volumes and cost reductions in key components (primarily the fuel cell system and hydrogen tanks).

In June 2017, the Bus Working Group organised an additional two hour in-person meeting to conduct a cost modelling session. The objective of this workshop was to agree on a common cost analysis for FC buses, mainly FC bus CAPEX and TCO. As shown in the figure below, the TCO analysis[20] suggests that FC buses could compete with battery electric vehicles, based on the 2020 target prices, with costs coming down further for larger production volumes.

[20] During the workshop, two approaches to defining the TCO environment for a fuel cell bus were reviewed. The first was based on a UK analysis, converted to euro. In general, it was felt that this differs quite considerably from the French situation. In particular the capital cost of all bus types is much lower for the UK (particularly the cost of electric buses), but fuel costs are lower in France. The second approach consisted in basing the costs on the CATP analysis of different drivetrains. With a few modifications, this was the preferred basis for the assessment.

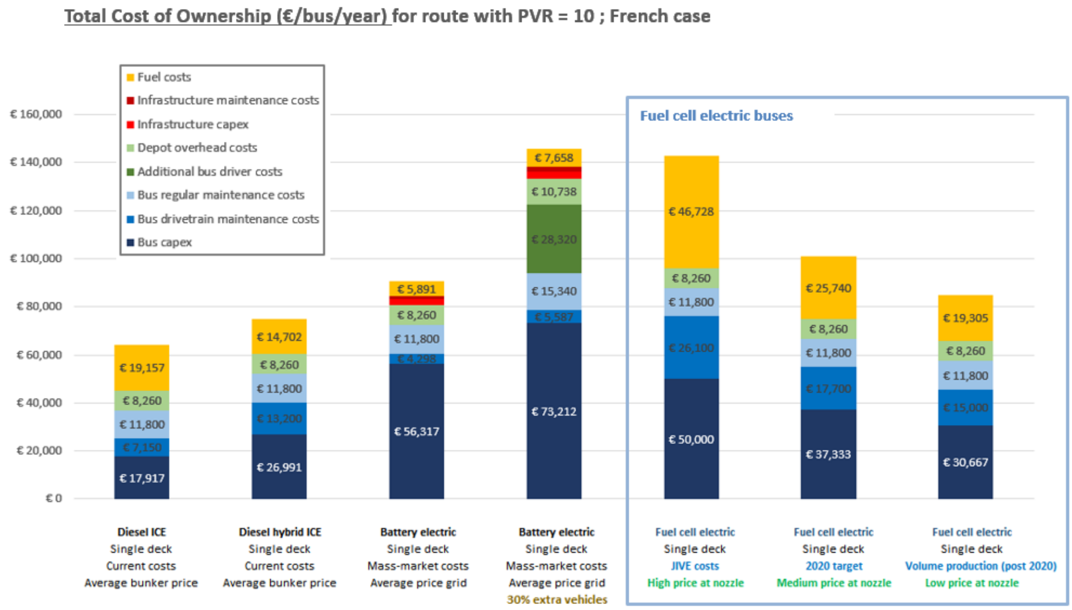


Figure 16: Results of TCO analysis for buses in the French cluster

The group also discussed different approaches to estimating the capital cost of the bus. In the end, a version influenced by the Ballard bus cost breakdown was adopted as the basis for the discussion. This led to a series of cost assumptions which will need to be validated by manufacturers through internal discussions. The discussion with Safra during the bilateral meeting in November 2017 suggests that this analysis and underlying assumptions are in line with their views, at least for the 'JIVE costs' and '2020 targets' cases – as it is still too early for them to assess post 2020 mass market costs as this depends heavily on component cost reductions which in turn depend on the overall scale of fuel cell bus deployments by that date.

Regarding the other bus manufacturers, discussions with LUTB (CARA) resumed in November 2017 (after being paused due to a change of personnel), with a first meeting on the 17th November 2017 and another meeting held on the 22nd December 2017.

Overview of the French FC bus projects

This section covers individual FC bus deployment projects in French cities. It should be noted that the information presented here will be subject to be modified as more information becomes available on each project. Some of them will be discussed during the new meetings which are to be organised with project developers (as described in the *Next Steps* section).

Pau SMTU

In January 2017, the city of Pau Béarn Pyrénées issued a public tender for the procurement of eight 18m articulated buses and their energy system for its BHNS ('high level of service') bus routes, operated by the STAP (public operator). The legal bidding procedure used was a 'competitive dialogue'. Firstly, this means that Pau did not ask for a specific technical solution, it only had to define functional requirements: this means it was open to all types of powertrains. Secondly, this procedure allows for several rounds of discussion between the bidders and the buyer, in order to develop the best possible solution while complying with the functional requirements. By July 2017, only two solutions remained on the short list: an articulated battery electric bus and a Fuel Cell bus (Van Hool, with Engie-GNVert and ITM Power for the energy system).

The fuel cell bus solution scored higher on operational requirements:

- Flexibility to extend the route at certain periods of the year;
- Resilience to potential energy infrastructure failures;
- Securing range margin while under additional energy-demanding constraints such as a particularly cold winter / hot summer.

Overall, the fuel cell option was more expensive than some of the other options, particularly in terms of opex (maintenance and energy), but due to Pau securing additional funding from Europe and the Nouvelle-Aquitaine Region, it was able to choose the best solution from a purely technical viewpoint.

The procurement contract between Pau and the chosen consortium (Engie, Van Hool, ITM Power) has been signed for delivery in 2019, with commercial operations to begin in the second half of 2019. The type of hydrogen production is still to be confirmed and will depend on negotiations regarding the electricity provided to produce hydrogen.

Planned bus depot in Pau

The project was publicly announced on the 31st of August by the Mayor of Pau and former French Minister François Bayrou.[21] He clearly stated that if everything goes as expected, the entire fleet (130 buses, 80% 12 meters) could be replaced by H_2 buses when they are due for renewal.

Auxerre

Auxerre is one of the three French cities in JIVE 2. In this project, green hydrogen will be produced using locally generated wind (~95%) and solar / hydroelectric energy (~5%). Five hydrogen buses will be deployed on the main bus route in Auxerre for the first part of the project (from 2019), and if this initial trial is successful, the FC bus fleet should be expanded to replace all buses in Auxerre, i.e. a total of 25 buses. The first five buses are expected to be partly financed via the region and the JIVE 2 project, which will be completed by the Auxerre agglomeration, that will own the buses and rent them to the bus operator (which is not identified at the time of writing as Transdev is the current bus operator, but a tendering process is on-going to renew the contract). The HRS tender is expected to be published in Q1 2018, for a public / private HRS to be used by the buses as well as some commercial fleet vehicles. The bus tender is also expected to be published in early 2018, for a start of bus operations in October 2019.

Toulouse HyPort

HyPort is an integrated hydrogen project covering a variety of aspects linked to hydrogen mobility. The project has been undertaken by the Occitania Region in cooperation with industrial and academic partners who, in 2016, received the French governmental label “Territoire Hydrogène” (Hydrogen Territory). It comprises four innovation projects (notably Safran) and an infrastructure project that will be incorporated in an SPV called HyPort SAS (a shareholders’ agreement has already been signed, the SPV agreement is expected to be signed in early 2018).

HyPort SAS will be a hydrogen production and distribution company, funded by the Occitania Region via its infrastructure investment company (COGEMIP) and Engie Cofely (via GDF Suez Energy Services). Large electrolysers (80 kgH_2/day and 235 kgH_2/day) and

[21] http://www.afhypac.org/documents/COMMUNIQUE%20DE%20PRESSE%20BHNS%20PAU%20B.pdf

HRS's will be deployed at the international airport of Toulouse-Blagnac and the regional airport of Tarbes Lourdes Pyrénées. Additionally, small electrolysers and stations around Toulouse and Tarbes will be deployed to create the foundation of a HRS network. The HRS tender is expected to be published in mid-2018.

During the project definition phase, it was decided that HyPort would also buy the first batch of vehicles necessary to ensure a sufficiently high H_2 consumption load and to demonstrate the appeal of the solution to all potential vehicle buyers in the area. HyPort plans to buy 5 buses (that should be in operation from 2019), 30 RE-H_2 Light Duty Vehicles and 60 H_2 bicycles. All the vehicles will be rented out to local administrations and companies as a complete package which includes fuel and maintenance. The current bus operator, Transdev, is on a three-year contract.

The company will acquire five 12m buses from a local manufacturer: Safra. Safra is considered by the Occitania Region as being a strategic asset for the local industry and in terms of employment. The buses will mainly operate around the airport, as parking shuttles, and on the tarmac between airport and planes. The plan is also for a local bus operator, Tisséo (servicing Toulouse and 32 surrounding agglomerations), to test one of the buses on a specific urban route, although this aspect is subject to further negotiations. The objective would be to convince Tisséo of the benefits of the H_2 solution, as they currently only use hybrids and natural gas.

GOGEMIP (Occitania Region) and Engie recently completed a tender (end of August 2017) for a complete technical and economic study that will define the exact configuration and location of the production and distribution sites. Because an international airport has many specific regulations, safety and security constraints will also be analysed. Another purpose of the study is to finalise the business model and the marketing offer for renting the various types of vehicles. It will also evaluate the feasibility of a green hydrogen option. Once the study has been completed (end of February 2018), the SPV HyPort SAS will be created and registered, and will launch the procurement process, as defined by the study referred to above, for electrolysers, HRS’s and vehicles.

As this project is part of the JIVE 2 project and the SPV HyPort SAS has not yet been created, Engie (through its subsidiary GDF Suez Energy Services) is the legal entity entering the Joint Agreement.

Versailles Grand Parc

In Versailles Grand Parc, the project to deploy two FC buses has been integrated into the 3Emotion project as a replacement for Antwerp. The two 13m buses will be provided to the STIF (local transport authority) by Van Hool and will be operated by the local bus operator SAVAC, with operations beginning in late 2018. The HRS is located in Loges-en-Josas and should be operational in January 2019. The HRS is being deployed by Air Liquide and is one of the stations included in the European H2ME2 project. At the time of writing (December 2017), the HRS construction has been completed, it is being tested and it should be used by hydrogen cars from mid-December 2017. The bus specific parts of the station will be integrated in Q1 2018, and the station opening is planned for March 2018. Air Liquide has committed to providing green hydrogen to the station with truck deliveries, and an on-site electrolyser is being considered for the second phase of the project.

Artois-Gohelle

This municipality benefits from funding (from various funds, notably FEDER) to completely renew the bus fleet and depots. They will mainly buy natural gas buses but 9 million euros have been provisioned for the introduction of six 12m FC buses. The municipality aims to start introducing full zero emission buses on a BHNS ('high level of service') route covering the Lens-Liévin-Hénin-Carvin territory. The six FC buses will be purchased and operated by the SMTAG (*Syndicat Mixte des Transports Artois-Gohelle* / '*Artois-Gohelle Mixed Union for Transport*'). The hydrogen bus project refers to the Master Plan of the "3rd Industry Revolution" undertaken by the Nord-Pas-de-Calais Region, contributing to 2 of the 6 pillars identified as necessary for the energy transition plan: the 3rd pillar (energy storage) and the 5th pillar (reinvent mobility).

The first phase of the public tender was issued in August 2017, the aim of which is to identify HRS and hydrogen suppliers. The tender is open-ended as far as the source of hydrogen is concerned, it has not been specified whether the hydrogen should be green or not, although it is clear that green hydrogen would be better in terms of scoring in the tender. The complete tender was sent to shortlisted bidders towards the end of September 2017. The hydrogen and refuelling station providers should be known in Q4 2017. The bus tender (including a pre-selection process) started at the end of Q4 2017.

Rouen

In the Normandie region, a network of small scale HRSs is being deployed via the EAS-HyMob project (partly funded by the CEF and the Region Normandie), which aims to install 15 HRSs and 250 light vehicles by the end of 2018. The Rouen Metropole is working on a project to deploy a fleet of three 18m FC buses and associated HRS.

The map and summary table below present a summary of these **six concrete projects**, totalling **29 buses**.

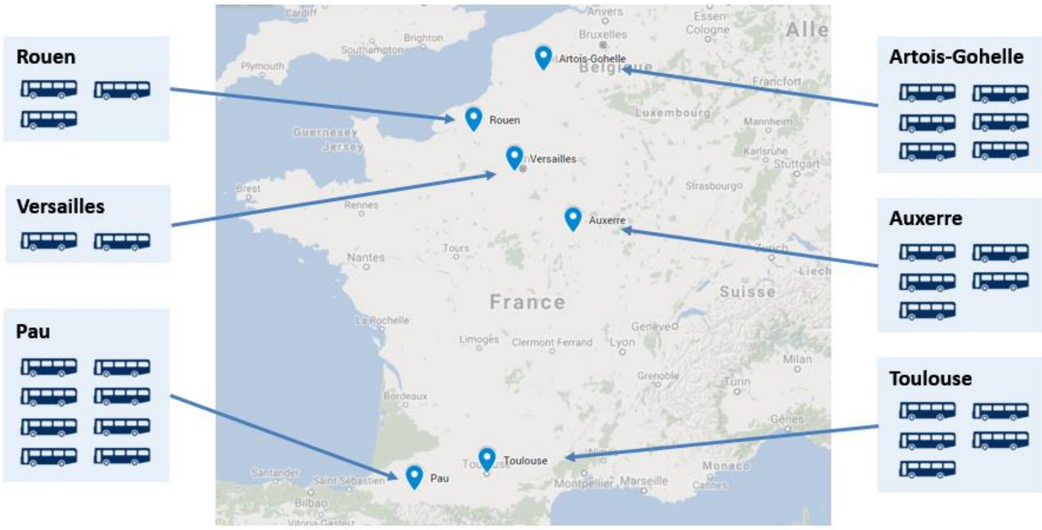


Figure 17: Locations of the FC bus projects planned in France

	European projects	Number of buses	Type of buses	Bus supplier	HRS supplier	Start of operations	P [%]
Auxerre	JIVE 2	🚌🚌🚌🚌🚌	12 m	Tender: 2018	Tender: 2018	2019	>90%
Artois-Gohelle	/	🚌🚌🚌🚌🚌🚌	13.5 m	Tender: Q4 2017- Q1 2018	Tender: Q3-Q4 2017	2019	>90%
Pau	JIVE 2 3Emotion	🚌🚌🚌🚌🚌🚌🚌🚌	18 m	Van Hool	ITM Power Engie/GNVert	2019	>90%
Rouen	/	🚌🚌🚌	18 m	*Date of the tender TBC*	*Date of the tender TBC*	2021	50%
Toulouse (HyPort)	JIVE 2	🚌🚌🚌🚌🚌	12 m	Expected to be Safra	Tender: 2018	2019	>90%
Versailles	3EMotion H2ME	🚌🚌	13 m	Van Hool	Air Liquide	2019	>90%

Figure 18: Summary of the FC bus projects planned in France

Paris

At the time of writing a request for proposals is on-going to replace 250 buses in Paris. These buses are expected to be 80% electric and 20% other alternative fuels. The decision is expected to be made at the end of 2017 and no announcements for hydrogen buses are expected within this time frame. The transport operator RATP expressed some interest in getting more information on FC buses, but clearly states it is only a 'technology survey', with no concrete plans. However, it should be noted that while publicly the city is engaged with battery electric buses, some concerns have been raised in informal discussions about this choice, e.g. they realised that it would not be possible to offer air conditioning with the electric bus while maintaining the required range, unlike what the OEMs had told them previously.

For the rest of the Ile-de-France region (i.e. all other departments within the region except Paris), another RFP will be issued in 2018 for 550 buses. For this second RFP, the French FC Bus Working Group members have initiated discussions with the STIF, the RATP and the regional vice-president for transport, in order to push forward the hydrogen bus deployment option.

Barcelona

In July 2017, the French bus cluster was contacted by representatives from the city of Barcelona who are currently examining the technical and economic suitability of fuel cell buses, to complement existing and planned deployments of battery electric buses. They have indicated that they intend to participate in the ongoing French bus cluster, alongside French cities, as the focus shifts to creating a concrete procurement programme. In parallel, Barcelona has joined the User Group in the JIVE 1 project.

3.3.3 Next steps

The next steps for the French FC bus cluster were discussed and validated by the French FC Bus Working Group. These next steps can be summarised in three axes, which are presented in the figure below.

Joint Procurements are necessary to generate economies of scale and permit the deployment of FC buses in France

Objectives

Identify the best option in terms of entity responsible for the joint procurement

→ Investigate the option of a joint procurement led by a city, based on the UK and German models,
→ Transport operator,
→ CATP ?

Engagement with cities and bus operators:

- Sharing of information, Q&A sessions, lessons learnt from existing projects
- Aggregating the demand, allowing to demonstrate the requirement for joint procurement
- Creation of a dedicated group

Engagement with bus manufacturers:

- Discussions about the plans and requirements to create a French FC bus offer
- Sharing of information about the demand for FC buses and market trends

End of 2017

On-going discussions and assessment of options

First phase in 2017; to be continued in 2018 to secure this group of cities

First phase in 2017; to be continued in 2018

Regarding the definition of a joint procurement involving the CATP, as discussed below, a specific meeting was expected to be organised in September (based on availability of the CATP) to discuss the process, timelines and how the French cluster can best coordinate with CATP teams to facilitate the process. This meeting has been rescheduled in February 2018. As previously discussed, the French Bus Working Group is also working on the definition of alternative options. In particular, the option of a joint procurement led by a city, based on the UK and German models, is being investigated. A meeting with Pau was organised on this topic, and the conclusion was that it was also a realistic option for French cities. At the time of writing, a new phase of communication with cities and discussion with city representatives is being organised to investigate this option. The current version of the joint procurement timeline is presented below (it is expected to be refined based on future advancements).

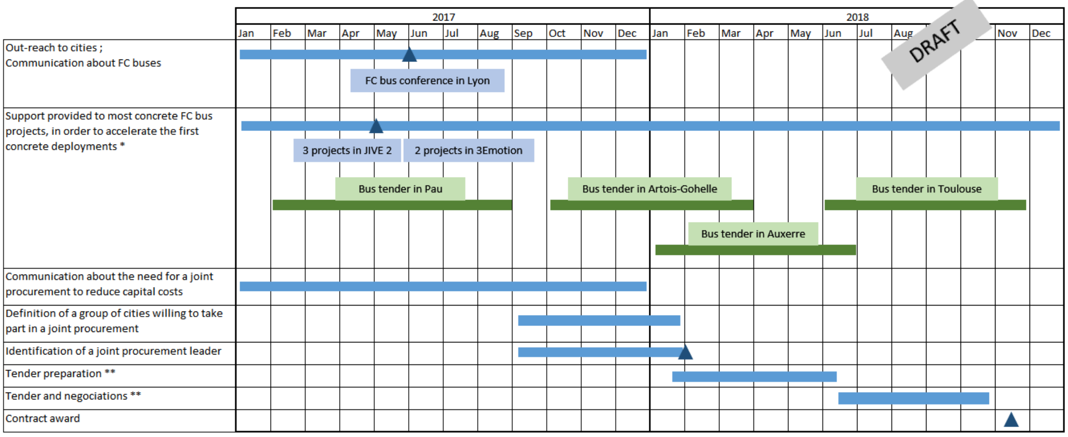


Figure 19: Gantt chart for joint procurement in the French cluster

* The dates for the bus tender in Rouen still need to be confirmed. There is no tender for the buses in Versailles, supplied by Van Hool.

** Based on lessons learnt from the joint procurements in the UK and Germany.

As discussed previously, discussions with French bus manufacturers have been initiated, and will continue, to investigate the potential of French FC bus models in the near future along with associated costs and required levels of demand.

Options for the French cluster after 2017

As presented in the previous sections, the French FC bus cluster has initiated a momentum within the French FC bus sector in late 2016 and 2017, noting that the sector is still at a very early stage in France. The cluster has been successful with various actions that were conducted in parallel. First, the analysis of the French bus market allowed for the identification of what appears to be, at this stage, the best option for joint procurements of FC buses in France, i.e. involving the CATP for their expertise. At the time of writing, discussions with the CATP are to be continued, and alternative options are being investigated. The option of a joint procurement led by a city, based on the UK and German models is of particular interest and is being investigated. In parallel, engaging with cities, regions and project developers who are trying to develop or are considering the definition of FC bus projects, allowed the French cluster to support individual projects, ensure they benefit from the experience of existing European projects, support them in their application for joining JIVE 2 and 3Emotion, etc. In that regard, Pau's official announcement on the 31st of August 2017 on the deployment of eight FC buses is a first that is expected to give other cities confidence in the technology. Early in-person meetings, the first full day workshop dedicated to hydrogen buses in France, and the creation of a group of cities interested in hydrogen bus projects, are creating momentum for this technology in France.

A majority of the French industrial entities supporting the uptake of hydrogen mobility in France are members of AFHYPAC and of the Mobilité Hydrogène France consortium that is AFHYPAC's mobility arm. This consortium was initially created to define the French strategy on hydrogen mobility and is the entity ensuring that all the key stakeholders in the hydrogen sector can meet regularly, work on common subjects and commonly define, revise and set up a national hydrogen mobility strategy. In 2016, the consortium identified the need to start working on FC buses in particular and created the French FC Bus Working Group. AFHYPAC is financed by its members subscriptions and ADEME, the French environment and energy management agency. AFHYPAC members pay an additional fee to be part of the Mobilité Hydrogène France consortium. Within the consortium, the FC Bus Working Group is financed by various sources: the FCH JU, AFHYPAC and additional subscriptions from the Mobilité Hydrogène France consortium. A large share of the total Mobilité Hydrogène France consortium budget is currently dedicated to the FC Bus Working Group.

Current members of the consortium recognise that the development of a bus deployment strategy is an important component of their strategic work, therefore the intention of the consortium is to continue working on the FC bus subject after 2017. Funding from the FCH JU in 2017 has been key to allowing more dedicated actions to be conducted such as supporting individual and concrete FC bus projects, extensive outreach to cities at different stages or preparation, etc. This FCH JU support is complementary to and adds significant value to the strategic work fulfilled under AFHYPAC's broader mandate. Should this FCH JU funding not be continued after 2017, the Working Group will re-centre its activities on more strategic work on buses, but would not have the resources to carry out the same level of interactions with the cities and to assist them in preparing for their first deployments. On the other hand, continuation of the FCH JU funding will allow the bus cluster to maintain its work on accelerating cities' preparations for large-scale joint procurements.

3.4 German cluster

3.4.1 Overview of activities to date

Context

The public discussion in Germany is currently dominated by the emissions of diesel vehicles and the question of how in cities the critical values, especially of nitrogen oxide emissions, can be met. For this reason, the federal government, the most affected cities involved and the vehicle industry have made agreements at the so-called “Diesel Summit”. Some of the cities from the bus cluster network, e.g. Hamburg, have also been involved in this process. According to the first results, a new funding scheme is to be created – with the aid of the industry (EUR 1 billion) – in order to convert public fleets to low-emission drives. One focus here is on public transport with buses. However, from the point of view of many municipalities the focus is not on the conversion to electrically driven buses, but rather the rapid replacement of older diesel buses by those of the pollutant class Euro VI. Nevertheless, an impetus was introduced via the partner cities to ensure that the procurement of fuel cell buses should also be taken into account in this program.

On 28 November 2017, a second meeting on this topic took place under the leadership of the German Chancellor Angela Merkel in Berlin. The aim of this meeting was to launch a timely implementation program for the improvement of air in cities with high nitrogen oxide pollution. As a result, a "2017-2020 Clean Air Program" with a focus on the conversion of vehicle fleets (city buses, taxis, car sharing, commercial transport) was proposed. In the area of buses, the program includes both the fast conversion to Euro VI and above all electric drives. This implies battery buses as well as those with fuel cells.

In total, 1 billion euros will be made available for the support of actions until 2020. Of this sum, 350 million euros will be used for the electrification of transport. The conversion to electrically powered buses should be supported by the Federal Ministry for the Environment, Building and Nuclear Safety (BMUB) with a funding rate of 80% on the additional costs. To this end, the BMUB had already initiated a corresponding notification to the European Commission in early 2017. Commission approval for this support program is expected in spring 2018. This would be a condition that - regardless whether funding of fuel cell buses by the FCH JU will be continued - attractive national funding opportunities for fuel cell buses will remain guaranteed in the coming years.

In addition to the funding of emission-free buses, the Chancellor has demanded in a press release a clear commitment of the automotive industry to emission-free drives, especially on buses, and a swift expansion of the vehicle range. This is supposed to be an essential criterion for the continuation of funding programs beyond 2020. This applies in particular to fuel cell buses, where the number of suppliers is very small.

Based on this basic willingness to promote innovative buses, other transport companies, for example Heidelberg, Erlangen and Leverkusen, have reported their interest in fuel cell buses. Depending on the further funding procedure, these discussions will be substantiated then by the cluster coordinators.

For cities and regions that plan to move to fully emission-free buses in the medium term, there are basically two alternatives, namely: battery buses or fuel cell buses with hydrogen as energy carrier. At this point, it should be noted that most transport companies, the political decision-makers as well as the industry associations, perceive that batteries have a lead. This might be due to the fact that batteries have been able to achieve major technical improvements (at least being promised by the manufacturers) and reach ranges which in many cases are sufficient for the daily mileage required (up to 250 km/day). Added to this is the fact that nearly all bus manufacturers offer battery buses, while the number of those who offer fuel cell buses is limited.

In parallel to the efforts to aggregate demand for fuel cell buses in the JIVE projects, a separate network for the co-procurement of battery buses (overnight charging) has been formed in recent months. Today, 15 of the major German transport companies, e.g. such as Berlin, Munich, Hamburg, Dusseldorf and Wiesbaden, belong to this network. Some of the partners have already started initial tenders and are currently evaluating them. This exercise reveals that the number of providers for battery buses is well above that for fuel cell buses. However, as the average range of the offered buses is around 150 to 200 km (depending on the use), pure battery buses do not provide a full solution for the majority of the bus fleets and the daily mileage needed. This means that on average only up to one third of the daily bus services can be covered by the participating transport companies without recharging. Accordingly, there are still further technical improvements necessary, in particular regarding the energy density of the batteries.

The discussions on fuel cell buses with the industry also revealed that some of the manufacturers (OEMs) have changed their future vehicle concepts, with a trend towards buses primarily based on batteries and potentially with a fuel cell as range extender. Depending on the manufacturer, within the range extender concept either battery or fuel cells are supposed to be used as the essential energy source. Since FCH JU is providing lower funding for range extender fuel cell buses, there is likely another obstacle to their market launch.

A focus in the discussion with the manufacturers was the question of when the next stage of development of fuel buses for everyday service can be expected. It was found that the development of battery buses is a priority both in time and in terms of development dynamics with most of the European bus manufacturers (Volvo, MAN, Daimler, Scania, Solaris). In this context, it is not expected that any of these manufacturers will be willing to provide the market with mature (pre-series) fuel cell buses before 2020. This reflects the situation in other European clusters that have already started the dialogue with the industry. In the case of manufacturers who are clearly committed to fuel cell buses (like Van Hool), it is aggravating that they have not yet made any clear statements regarding the expansion of their production capacities. At present, delivery times are expected to be 18 months and production rates of one unit per week, which both will hinder rapid deployment following firm orders.

Against the background of these difficulties on the manufacturing side, it has not been possible yet to enlarge the German-Italian cluster with other partners with precise deployment plans, although some regions are expressing a general interest (see below). Therefore, possible options, such as how to increase the willingness of the industry to build fuel cell buses and how to use results from the JIVE project (as soon as they are available) to address further regions, should be a priority for the future measures. In addition, it must be observed, in particular for Germany, how the results of the Diesel Summit will affect the demand for fuel cell buses and thus how the already active as well as other manufacturers can be motivated to develop and supply more fuel cell buses for the market.

Joint procurement of fuel cell buses

During early 2017 the participants in the JIVE project thoroughly revised and further detailed the technical specifications for the joint procurement of fuel cell buses. In addition to working on the specifications, an assessment matrix for assisting in the evaluation of incoming offers was defined. An important part of these activities was the adaptation of the bus specification in order to meet the demands of all procurement partners. In addition, the evaluation matrix was revised to reflect the different expectations of the operators (more and less important technical criteria).

After completing the specifications and this evaluation matrix, an official procurement exercise with a required prequalification was launched in accordance with European regulations for public companies in the German cluster. The tender was published on TED on May 18th 2017. This process was mainly coordinated by the Wuppertaler Stadtwerke (Wuppertal municipal utilities) and RVK (public transport company in the Cologne region) with support from the cluster coordinators. The partners from the Rhine/Main region and from Bolzano have been involved in this task too. The status is as follows:

- The evaluation of the applications after the June 12 deadline showed that there was no candidate meeting all the criteria mentioned in the prequalification. For example, some manufacturers were unable to provide test vehicles and other applicants did not have evidence of prior use of fuel cell buses.
- Since the fulfillment of these criteria is a precondition for the qualification of the applicants, the tender was formally canceled on June 19, 2017.
- A pan-European call for fuel cell buses in the negotiation process without prequalification was then initiated.
- In addition to the companies that already took part in the tender, the consortium actively addressed other bus manufacturers believed to be well placed to offer fuel cell buses in an attempt to cover the broadest possible range of providers.
- A total of seven companies received the specifications developed by the partners.
- Due to the summer holidays and the related absences of contact persons the given deadline for the submission of tenders was extended to September 12, 2017.

A summary of this tender process is as follows:

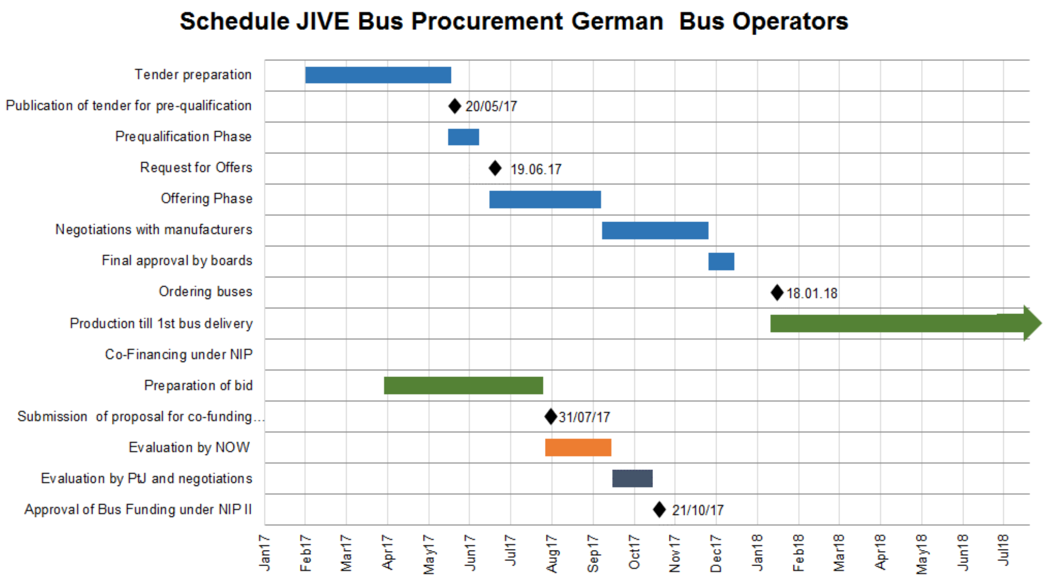
- From the seven OEMs that downloaded the specification, only two submitted offers for their buses.
- One of these two offered only for two lots, namely RVK and WSW. The supplier declined to submit offers for the other locations mainly due to the long distances between them, which would make aftersales support difficult.
- One of the OEMs could not deliver any references, was unable to provide a test vehicle and according to the evaluation of the consortium was therefore not reliable enough to be able to deliver such a high number of fuel cell buses.
- Based on the process of tendering fuel cell buses in the negotiation process without prequalification, both RVK and WSW decided to proceed with one OEM and exclude the second one.
- That means, only RVK and WSW from the German cluster had the chance to negotiate with the OEM. Rhein-Main and Bolzano are now free to select an OEM of their choice.

Lesson learned:

- Unfortunately, some of the OEMs that in 2016 indicated their intent to offer fuel cell buses were unable or unwilling to respond to the tender at this point in time.
- Currently, only Wrightbus and Van Hool are in a position to offer buses and meet the requirement of the joint tender in the German cluster. Of these suppliers, only Van Hool has experience in building left hand drive buses.
- Even though Daimler, Solaris, VDL and other manufacturers communicate their possibilities and ambitions, they are not currently willing to offer fuel cell buses.

- If the manufacturers argue that this development would be a result of the complicated specifications of the German tender, this does not reflect sufficiently the expectations that the buses to be delivered now have to be technically stable and in line with market requirements.
- The main reason for this disappointing response appears to be that many of the incumbent bus OEMs in mainland Europe have not yet decided on the optimal technical solutions for zero emission buses. Given that these companies have limited engineering resources available, the current focus on battery electric buses appears to be restricting the rate of progress on the fuel cell option. However, a couple of manufacturers e.g. Daimler have announced to provide fuel cell buses (range-extender) as a series after 2020.
- For a cluster-wide identical tender it is necessary to find a simple specification and at least a uniform bus. But since every customer has different requirements (topography, length of lines etc.) and wishes regarding the equipment, e.g. driver's working place, announcement system, number of seats, doors, it seems that a joint procurement of an identical bus in the German public transport bus business is a larger challenge than expected.

The latest Gantt diagram for the procurement of the buses in the German cluster under JIVE is given below:



Funding from national schemes

After an intensive discussion between NOW and the cluster coordinators, the so-called "Market Activation Directive of the NIP" (National Innovation Program for Hydrogen and Fuel Cell Technology) has been published in the Federal Gazette (www.bundesanzeiger.de) under the title "Announcement of the Funding Directive for Market Activation Measures within the National Innovation Program Hydrogen and Fuel Cell Technology Phase II" („Bekanntmachung der Förderrichtlinie für Maßnahmen der Marktaktivierung im Rahmen des Nationalen Innovationsprogramms Wasserstoff- und Brennstoffzellentechnologie Phase II“) in March 2017. With this funding guideline, fuel cell buses from JIVE can be co-financed (note: the guidelines also include other fuel cell vehicles, electrolysis systems, cogeneration plants, and fuel cell based UPS systems) in line with the European regulations also on national level. The funding amounts to a maximum of additional 40% of the surplus investment costs of a fuel cell bus compared to a conventional diesel bus. Hydrogen refueling stations are funded with up to 40% of the investment (not only extra costs) but there is no funding for workshops or operating costs.

Following the publication of the directive, the Federal project management organisation PTJ (Projektträger Jülich) has launched a project call for the funding of inter alia fuel cell buses in public transport: (/now-gmbh.de/content/2-nationales-innovationsprogramm/2-foerderprogramm/nip2_foerderaufruf_oepnv_02_2017.pdf). This call specifically refers to the calls made by FCH JU:

- FCH-01-9-2016: Large scale validation of fuel cell bus fleets;
- FCH-01-5-2017: Large scale demonstration in preparation for a wider roll-out of fuel cell bus fleets (FCB) including new cities – Phase two; and
- FCH-01-6-2017: Large scale demonstration of Hydrogen Refueling Stations and Fuel Cell Electric Vehicle (FCEV) road vehicles operated in fleet(s).

The deadline for applications was July 31, 2017. The corresponding applications were submitted by the German partners in JIVE by this date. These include for Wuppertal the procurement of 10 buses and one electrolyser, for Düsseldorf 10 buses, for RVK Cologne 30 buses, for Wiesbaden and Mainz 4 buses and for Frankfurt 3 vehicles with an additional funding to the FCH JU. NOW, as the supervising authority responsible for the applications, has confirmed the receipt of the application and further detailed and processed the applications for funding with the applicants in terms of both technical and administrative aspects.

In November, RVK as the first applicant has received the confirmation for the funding under NIP. For the others approval is expected by the end of 2017. It is intended that a similar call from NOW under the NIP II program for fuel cell buses will follow in spring 2018. This call could then be used to co-finance the buses under JIVE 2 and in other German locations. Besides the prolongation of NIP, additional funding opportunities may arise from the political decisions made at the *Diesel Summit*.[22]

Besides the activities on the federal level, public transport companies from the German state of North Rhine-Westphalia (NRW) are expected to receive funding of fuel cell buses with up to 60% of the additional investment costs. This directive has just been published. As these funds originate from federal support for the Länder, it does not conflict with EU funding and

[22] The “Diesel Summit” was a meeting between German ministers and leaders of Germany’s major automotive OEMs held in September 2017 at which measures to address concerns over pollution from diesel vehicles were discussed, with the aim of avoiding Mayors of German cities implementing bans on certain vehicles.

could thus support coming initiatives for the acquisition of next generation fuel cell buses in the future.

In Bolzano, in addition to the preparation of the procurement plan for the buses an implementation of the results of the FCH JU-sponsored study NewBusFuel is being prepared. Hydrogen production is to be installed directly to the electricity production, for example, from a waste incineration plant. Thus, for example, the line costs can be significantly reduced. This concept is the basis for a funding with the region's own resources which still needs to be developed in detail.

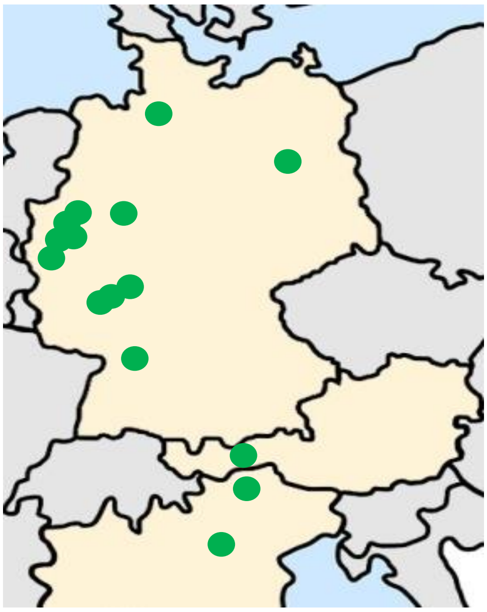
Refueling Stations

Regarding the funding of hydrogen refueling stations, the coordination for the stations in Cologne/Hürth with RVK is already underway within the framework of the European joint project MEHRLIN. The federal states of Hesse and Rhineland-Palatinate have provided their own funding for the hydrogen refueling station in Mainz.

Regional funding may become even more interesting in the context of the decision within the Diesel Summit that a complementary use of national as well as regional funding will be allowed.

Cluster management and overall demand for fuel cell buses

Following the example of Germany also in Austria there is a growing interest in fuel cell buses. Thus Innsbruck as the first region in Austria has now become official member in the cluster. The region is represented by the operator "Innsbrucker Verkehrsbetriebe und Stubaitalbahn GmbH" (IVB) as well as by the regional Department for Transport. Therefore the cluster now consists of 16 active members.



1. HOCHBAHN Hamburg
2. ViP – Verkehrsbetriebe in Potsdam
3. Stadtwerke Münster
4. Verkehrsverbund Rhein-Ruhr
5. Wuppertaler Stadtwerke
6. Regionalverkehr Köln
7. Rheinbahn Düsseldorf
8. Mainzer Verkehrsgesellschaft
9. ESWE Wiesbaden
10. TraffiQ Frankfurt
11. Stuttgarter Straßenbahnen
12. Ruhrbahn GmbH
13. moBiel Bielefeld
14. Innsbrucker Verkehrsbetriebe (Tyrol, Austria)
15. Bozen and Bruneck (South Tyrol)
16. Rovereto (Trento).

Figure 20: Map of Cities involved in the German/Austrian/Italian cluster

Regarding a further expansion to Austria the cluster coordinators have been in intensive contact with the regional government of Tyrol as this region is particularly committed as an intermediary to other Austrian transport companies with an interest in fuel cell buses. A special workshop dedicated to hydrogen in public transport is planned for January 19, 2018.

The agenda includes presentations on the lessons learnt from operators who have experience with FC buses (RVK; SASA), information about FC bus commercialisation plans supported by the FCH JU and other funding opportunities as well as a status on the developments in bus manufacturing. The aim of the workshop is to convince other Austrian cities, like Vienna or Graz, to join.

Specific data on the locations and their status e.g. regarding hydrogen infrastructure in the cluster, are given as follows:

City	Population	Bus fleet size	Operators	Number of bus HRS	Comments
Münster	310.000	130	Stadtwerke Münster	1	new refuellling station since 2017 combined cars and buses
Hamburg	1.860.000	850	HOCHBAHN	1	numbers for HOCHBAHN, overall 1.500 buses in Hamburg
Stuttgart	610.000	280	SSB, Stuttgarter Straßenbahnen AG	1	new HRS on bus depot in 2017
Cologne Region	2.100.000	300	RVK, Regionalverkehr Köln	1	buses only RVK; further 320 buses riding on behalf of RVK; HRS: plus 2 more in 2017/18
Potsdam	170.000	70	VIP, Verkehrsbetriebe in Potsdam	0	momentarily no refuelling station available
Mainz	212.000	150	Mainzer Verkehrsgesellschaft	0	1 refueling station to come in Mehrlin, 1 funded by local authorities
Wiesbaden	290.000	250	ESWE, Stadtwerke Wiesbaden	0	
Frankfurt	730.000	300	TraffiQ Frankfurt	1	
Wuppertal	350.000	300	Stadtwerke Wuppertal	0	Refuelling station in planning
Düsseldorf	630.000	430	Rheinbahn AG	0	refuelling station in planning
Bielefeld	330.000	90	MoBiel, Bielefeld	0	no refuelling station available at the moment
Innsbruck	132.000	180	IVB	0	elctrolyser H2 supply from Demo4grid project available
Bozen	520.000	160	SASA AG	1	new refuelling station in planning, energy from garbage plant
Rovereto	540.000	690	Trentino Trasporti Esercizio	0	Inhabitants Region Trentino

Detailed information on the developments in the German and Italian members of the cluster are illustrated below.

- **Rheinbahn Düsseldorf** has continued its efforts and has become a partner in the application for JIVE 2 in April 2017 with 10 buses. The JIVE 2 application has successfully climbed the first hurdle and the negotiations on the grant agreement will be finished in December 2017. Beside the activities of the Rheinbahn, the

Stadtwerke Düsseldorf are planning to use electricity from their waste incineration plant to produce hydrogen. This hydrogen could then be delivered to the Rheinbahn at attractive prices. Alternatively, Rheinbahn is checking the option of an HRS which is constructed and operated by a third party, so that Rheinbahn would have no investment and operating cost on their balance sheet. They would only have to pay for the consumed hydrogen. The price of hydrogen varies as the HRS operator distributes the investment costs over the total amount of dispensed hydrogen.

- **RVK (Regionalverkehr Köln)** has continued the operation of their two Van Hool buses. RVK is still very satisfied with the high reliability of the two vehicles. RVK is also participating in the bid for JIVE 2 with another 15 buses and is partner in MEHRLIN. Because the HRS in Wermelskirchen was not tendered[23], it is currently reviewed by INEA if the funding from the MEHRLIN project can be claimed by RVK. The preparation of the tender for the civil works of the new stations is on the way and will be published early 2018 with construction works starting soon after. Parallel to this, the existing station in Hürth shall be upsized in order to be able to supply more buses. For this project the engineering is about to start too.

- **WSW mobil GmbH (Wuppertal)** is in the lead for the coordination of the joint procurement in JIVE. Unfortunately, the result of the collaborated tender is that only two of six batches (RVK and WSW) have an offer. The other partners now have the chance to find a manufacturer for FC-buses by direct award of contract. In the meantime WSW is going to finalise the tender process with one of the OEMs.
  WSW also wanted to participate in JIVE 2 with another 10 buses, but due to the high demand and the lack of sufficient funding, they agreed to refrain from a procurement and join as an observer. However, if one of the current participants should step back for whatever reason, WSW is prepared to join as bus procurer immediately.
  Regarding the H_2 station, AWG Abfallwirtschaftsgesellschaft mbH Wuppertal (AWG) as a sister of the WSW mobil GmbH has opened the tender at the 20th November, 2017.

- The partnership between **Mainz (Mainzer Verkehrsgesellschaft)**, **Wiesbaden (ESWE)**, **In-der-City-Bus GmbH (ICB)** and **Frankfurt (traffiQ)** is now finalized with all legal requirements. Beside the existing station in Frankfurt-Hoechst (which is the designated HRS for the Frankfurt buses) an additional station for the 8 buses in Mainz and Wiesbaden will be built. The partners will receive a regional subsidy for the stations. On July 31st a handover ceremony of the official grant notifications took place with the two federal states involved (Rhineland-Palatinate and Hesse). Thus, the funding (2m euros) for building the second HRS is confirmed: The design planning has just recently begun. The start of the construction is scheduled for Q2/2018, with a commissioning planned in January 2019.

  The joint procurement of FC buses did not result in satisfying offers for the Rhein-Main region, therefore the partners have to re-evaluate the tender individually with OEMs via a “free contracting approach”. Rhein-Main have therefore contacted the relevant OEMs again beginning of December. Two of them reacted immediately saying that they would not send a quote, one is expressing concerns that they can meet the deadlines for delivery due to full order books. Answers from the others are pending.

  After having evaluated the next steps, it is planned to place an order in Q1/2018. In addition to fuel cell buses (FCEV), each of the three PTOs plans to procure battery

[23] The main parts of the HRS are part of an R&D project funded by the German NIP program.

electric vehicles (BEV). Both technologies are considered as important steps in order to implement emission-free public transportation. In the future it is expected to have a combination of BEVs and FCEVs utilizing the advantages of each technology. Especially for longer routes and for flexible operations the partners assess the fuel cell bus to be superior.

- **Stadtwerke Münster** (SWM) are procuring FC buses outside the JIVE project. In the meantime, they have ordered two buses from ebeEUROPA. These buses are equipped with fuel cells working as range extender from HyMove in the Netherlands. The buses will be delivered in spring 2018. Münster will use an already existing public HRS which offers 700 and 350 bar refuelling. This HRS is very close to their bus depot. As long as the fleet is small, the operator believes that this is very suitable and a low cost solution to start with FC buses as this saves the costs of an own station. In the meantime, SWM has already bought two HyKangoos and will train their drivers on hydrogen refuelling and equip their workshops with hydrogen safety devices such as sensors etc. SWM is clearly seeing a future for FC buses for longer driving cycles between the city of Münster and the surrounding villages. On the other hand, from the current perspective they will mainly operate battery buses with opportunity charging on smaller routes.
- **Essen (operator Ruhrbahn GmbH)** has finalised their feasibility study on electric buses. Regretfully, the results will not be published. Internal information indicates that a transformation of the fleet to electric buses will be postponed until 2020 when a larger variety of battery and fuel cell buses will be on the market, maybe also at lower prices. While a small battery bus project with two buses is under discussion, a larger zero emission bus project is currently unlikely. However, based on personal communication, Essen appears to still be in favour of fuel cell buses.
- **Bielefeld (operator moBiel GmbH)** had applied for a funding program for municipal investments, but the proposal was not successful. Nevertheless, they still plan to introduce four FC buses into their fleet plus one HRS. With regards to the HRS, Bielefeld is already in discussion with HRS providers about various options of operation. The Supervisory Board of moBiel has recently formally decided to acquire 4 fuel cell buses which are to receive funding from the corresponding program of the state of North Rhine-Westphalia.
- **Potsdam** is planning to start with the first up to three articulated H2 buses in 2021. Currently they are discussing the implementation strategy in their board. A decision on this could probably benefit from funds from the National Innovation Program (NIP).
- **Bolzano** is participating in JIVE with 12 buses. Actually, Bolzano is involved in the common tender exercise with the German Cluster. As only a few lots (partners) received an appropriate offer, Bolzano and other partners have to run a second procurement exercise in early 2018. They will follow a similar approach as Rhein-Main. In the meantime Bolzano has started the preliminary work for tendering the upgrade of the HRS in order to be able to serve the actual fleet of 5 buses and the additional 12 buses. This infrastructure is planned to be operative in 2019 within the MEHRLIN project. Besides, South Tyrol is planning to procure emission-free buses only after 2025. In the meantime, FC and battery buses are tested as the two alternatives. On this way an innovative approach for hydrogen production will be targeted in order to reduce the production costs and to reach nearly comparable price to a diesel-based operation.

- **Rovereto** is currently in discussions about further detailing their activities on emission free public transport and thus decided not to participate in the bid for JIVE 2 but are actively following up on all ongoing discussion within the German/Italian cluster.
- In **Hamburg,** bus transport companies are required by the municipal government to procure only emission-free buses from 2020. In order to evaluate the various innovative drives with regard to their performance, battery buses, plug-in hybrid buses, fuel cell buses and battery buses with fuel cells as range extenders are tested on the innovation line. At the same time, all depots were investigated to understand whether they (a) could be adequately supplied with hydrogen, or (b) provide sufficient capacities for the supply of electricity within a 4-hour time slot at night. The evaluation according to (a) showed that at the larger depots and if the storage volume is or exceeds 5 tons, problems regarding the distance to the neighbors can arise. In option (b), supply from the electricity network is possible without bottlenecks, but a connection to the high voltage grid (110 kV) is necessary for the largest depot (260 buses). In June 2017 the local public transport agencies have decided to procure 70 battery buses until 2020. The offers have been received in November 2017 and are currently being evaluated. For reasons of confidentiality, no detailed information can be passed on but nevertheless it should be noted that the number of offers of corresponding vehicles is in line with the expectations. In addition, it can be assumed that the prices for battery buses are below the threshold value for fuel cell buses set by the FCH JU of 650, respectively 625 kEuro. The mandatory range of the battery buses is specified with at least 150 kilometers (with fossile heating). This can cover about a quarter of the daily mileage. At the same time, the need for further technical solutions to ensure a sufficient range and flexibility for the entire daily performance of the bus fleet is shown. Against this background, hydrogen and fuel cell technology continues to be a relevant option for the HOCHBAHN. Therefore, the 6 fuel cell buses currently in use (4 from Daimler Buses and 2 battery buses with fuel cells as a range extender from Solaris) will continue to be in operation. In addition, HOCHBAHN has agreed to extend the financial support with H2-Mobility as the responsible consortium for the hydrogen refuelling station in the HafenCity until 2021.
- Currently, the **Innsbruck** Transport Authority (IVB), in coordination with the province of Tyrol and the Tyrolean Transport Association (VVT), is researching which drive technologies are available on buses as alternatives to conventional diesel aggregates and how these alternative technologies could be used in Innsbruck. For this purpose, the search procedure has been divided into battery (VVT) and fuel cell (IVB). An event in Innsbruck next January held by the Province of Tyrol and the IVB intends to make hydrogen more accessible to a broader audience. At the moment there are no concrete projects for alternative drive technologies at the Innsbruck public transport companies and there hasn't been a decision for a specific drive system yet either. Furthermore, currently there is no intention of cooperation between the Innsbruck transport companies and other hydrogen projects planned in Tyrol.

At present, the concrete demand for fuel cell buses in the cluster are:

City	No. of FC buses				Total for pre-2020 projects	
	Projects beginning in 2017/18		Future projects			
	12m	18m	12m	18m	12m	18m
Münster	2			10	2	10
Hamburg						
Stuttgart						
Köln	45				45	
Potsdam				3		3
Mainz-Wiesbaden-Frankfurt	7	4	7	12	14	16
Wuppertal	10		10		20	
Düsseldorf		10				10
Bielefeld			4			
Karlsruhe					4	
Innsbruck (Tyrol)			10		10	
South Tyrol	10	2	10	5	20	7
Rovereto			10		10	
TOTAL	**74**	**16**	**51**	**30**	**125**	**46**

Potential new members, show of interest

Based on a growing awareness for hydrogen buses and the ongoing discussion on air-quality requirements beside the existing operators in the cluster, some other German cities have indicated an interest in FC buses and have stated first talks with the cluster coordination team:

- Erlangen (Stadtwerke Erlangen) sees FC buses in contrast to battery as the favourite option for their city. In early 2018 Erlangen will a get a public HRS built by H2Mobility Germany. The plan is to expand that station with a dispenser for buses. Having this opportunity, they want to start a smaller demo project with two FC buses. However, Erlangen is still in the fact finding phase.
- Heidelberg as city has clearly voted for FC buses. The reason is the challenging topography with lines climbing 350 metres up to the surrounding Odenwald. Their local fleet is with 40 buses relatively small (operator RVM). Most of the inner city transport is done by trams. Nevertheless, Heidelberg wants to change their complete fleet to fuel cell buses in the mid-term. The plan is to start with 4 buses end of 2018. Soon, a feasibility study will begin examining also solutions for the H2 infrastructure. As RVM is also operating buses in Mannheim and Ludwigshafen, a regional FC bus line is another option.
- Leverkusen (wupsi) wants to profit from their vicinity of the Bayer chemical plant and the huge amounts of hydrogen being produced there. They are currently discussing with hydrogen providers how the HRS could be supplied from the Bayer plant.

The cluster coordinators are currently intensifying talks with these cities in order to integrate them into the joint network

In addition to the other German cities different cities in Italy, which were not yet involved in the discussion, have indicated at least a general interest in fuel cell buses, especially in Italy. These cities are listed in the following table including an estimation of the likeliness of the realisation.

In further talks with these cities the coordinators will strive to get a better understanding of the maturity of their plans. Depending on the results it might become necessary to install a separate cluster manager for Italy in order to facilitate the internal communication (in Italian). This should be taken into consideration if the cluster coordination work should be continued beyond 2017.

These decisions should be facilitated with the ongoing activities in the FCH JU working group “Heavy Duty vehicles” in the *Regions* study coordinated by Roland Berger as there are more interested regions in this working group, especially from Southern Europe. In addition, the "Hydrogen Valleys" which are being developed in the context of this study could be compared as to whether fuel cell buses are already in operation or planned to deploy at these locations. Regions qualifying as "Hydrogen Valley" but not yet integrated into the Cluster for Fuel Cell Buses could then be actively approached and involved by the regionally responsible cluster coordinators. Since the "hydrogen valleys" are expected to be determined not before 2018, a continuation of the work of the cluster coordinators would be a criteria for such an approach.

The following table shows the current potential for FC buses in the cluster. The column “possible buses” of the following table shows numbers that partly stem from the information of the current Roland Berger study, partly from personal talks of the cluster coordinators with PTOs. It should be noted that these numbers reflect expectations more than concrete planning as in most cases (except e.g. Heidelberg) the decision on which emission free drive train shall be selected is still open. On the other hand the numbers can rise significantly if Diesel based vehicles should be banned from inner city areas.

	No. of FC buses by category			
	In service	Funded	Very likely	Possible
Münster		2		10
Hamburg	6			
Stuttgart	4			50
Köln	2	30	15	100
Potsdam				3
Mainz-Wiesbaden-Frankfurt	2	11		
Wuppertal		10		10
Düsseldorf			10	60
Bielefeld				4
Karlsruhe	2			
Heidelberg				40
Erlangen			2	10
Northern Ruhr Area				50
Innsbruck (Tyrol)				10
South Tyrol	5	12		10
Rovereto				10
Milano	3		7	
Torino				10
Venezia			10	
Roma			10	
Napoli				10
Bari				10
Sanremo		3		
Capo d'Orlando	1		4	
Ravenna	1		4	
Total	26	68	62	397
Cumulative total	**26**	**94**	**156**	**553**

Table: Total number of FC buses currently discussed in the cluster

With these recent developments and compared to the initial CHIC project or from the 27 fuel cell buses currently in operation, a dynamic increase is nevertheless visible regarding the participation in JIVE (63 buses) and JIVE 2 (another 25 buses) in a scale ranging to potentially more than 200 buses until the end of the decade.

Within the cluster, the need for consultancy services of the German transport companies is largely restricted to the available funding instruments. Development of business models, calculations of TCO etc. are mostly carried out by the companies themselves. However, several operators in Germany have started feasibility studies how an emission free public transport can be realized in their cities. The reason is the ongoing discussion on city access restrictions for Diesel vehicles and the potential funding within the expected new calls for innovative buses from the Diesel Summit. However, it can be stated that the corresponding consultant companies doing the studies are not very well informed about the state-of-art and the cost situation of today's fuel cell buses. The result is that in most studies FC buses and hydrogen are regarded as being far too expensive compared to battery bus solutions. In those cases where the cluster team becomes aware of such studies, we try to inform the operators about the actual developments and provide them with realistic costs. In order to further reduce this problem, the cluster coordinators agreed with NOW to develop their own standardized assessment tool for the procurement of innovative buses, which shows the respective application possibilities, the costs as well as the functional advantages and disadvantages of battery and fuel cell buses. This tool can then be used by the transport companies to prepare system decisions, it provides a uniform and systematic evaluation standard and/or promotes knowledge about fuel cell technology in particular.

Following the face to face meetings of the cluster in 2016, communications between the cluster members have now mostly been either in bilateral meetings e.g. regarding the procurement as well as via telephone conferences and with the overall network and new respectively already integrated individual members. The main topics of the communication were the current tender as well as the applications for funding from the German NIP scheme.

Through coordination between the cluster coordinators and the Federal Ministries of the Environment (BMUB) and Transport (BMVI), regular meetings of all German transport companies operating innovative buses (plug-in hybrids, battery, fuel cell) were initiated in order to consolidate the experience exchange (Bus AG). While the operators of fuel cell buses have not been involved in these meetings so far, in the future they will have an active role in this network. This creates a good condition for immediate discussion as well as clarification the current state of development and the advantages of the fuel cell buses for the transport companies. The next Bus AG meeting will take place on 19 December in Berlin. Heinrich Klingenberg as one of the cluster coordinators will be one of the moderators.

Dissemination activities

Working closely with the German Public Transport Association (Verband Deutscher Verkehrsunternehmen, VDV), the German cluster coordinators helped to plan a workshop focusing on innovative buses (Battery, Hybrid, FC, CNG) that was held in Cologne on July 12th 2017. With participation of more than 140 representatives from regions, cities and bus operators, this event was a great success. After the presentations and discussions participants were invited for test rides with two battery buses (VDL and Sileo) and two FC buses (Van Hool and Ursus). During the workshop, a number of operators asked for more information about FC buses. The cluster coordinators are now following up on these expressions of interest.

Other activities and discussions on hydrogen technology for buses include, among others, in the last quarter of 2017:

- Frank Koch gave an overview about the European fuel cell bus activities during the 30th International Electric Vehicle Symposium & Exhibition (EVS30) in Stuttgart mid October 2017.
- Heinrich Klingenberg received a Japanese delegation from JRRI on Oct 23 and discussed the potential integration of Japanese FC buses in Germany.
- RVK presented its activities on the congress “Klimaschutz in Kommunen” on November 22 in Wuppertal.
- Among others, the projects JIVE and MEHRLIN were presented on the 17th Annual meeting of the Fuel Cell and Hydrogen Network NRW on November 30, 2017.
- On 24th of November, a HOCHBAHN fuel cell bus was introduced at the opening of the 5-megawatt electrolyzer at an industrial company in the Port of Hamburg.
- On December 6th Heinrich Klingenberg gave a presentation at the workshop “TRENDS” in Aachen.
- On December 11th, the fuel cell bus of RVK together with fuel cell passenger cars were shown at a presentation of the Shell Hydrogen Study in Düsseldorf.

3.4.2 Planned next steps

In addition to the intensive coordination of the technical definition of the buses within the German cluster, there has been a constant exchange with the coordinators of the Northern European and Benelux clusters to determine the extent to which the specifications can be adopted by the other clusters, with a view to achieving further standardization. These discussions have been intensified in a face to face meeting of the German, Dutch/Belgian as well as the Northern/Eastern European cluster coordinators in Düsseldorf on June 27th 2017. Even if it has become clear that the commercial and legal framework conditions are so different that a full joint procurement is not recommended, the specifications will be harmonized based on the text developed in the German cluster to safeguard as much scale effects as possible.

Planned next steps within the German cluster to inform cities / regions about funding opportunities and potentially enlarge the number of interested cities are:

- The common specification sheet developed for the German tender is now available for any interested bus operator. As an example, the cities of Bielefeld and Potsdam have already asked for it as they are currently in discussion with local politicians to go for electric buses and evaluate battery and fuel cell based solutions.
- The cluster coordinators together with NOW and VDV are realising the assistance tool for all interested transport companies which intend to buy electric and / or fuel cell buses to support the transformation process from diesel to clean bus drives. The tool is an easy to handle instrument to help transport agencies with a clear and quick evaluation of which solution will be the most suitable for them. The instrument is expected to be available from the second quarter of 2018 and then will be actively offered to transport companies as part of an information campaign.
- Together with colleagues from Innsbruck, the cluster coordinators will organize the preparation of the workshop on January 19th, 2018 in order to convince further cities in Austria to go for fuel cell buses.
- A similar workshop in Italy to get into contact with the new cities mentioned in the table above is being planned.

- The support for newcomers like Heidelberg, Erlangen, Leverkusen and other cities will be continued. Detailed talks are planned for the beginning 2018.
- Since the next joint meeting of the German-Italian bus cluster is expected to take place in mid-January 2018, these interested parties should be actively involved in the network.
- Cities participating in the EU Hydrogen Regions and Cities Initiative and which are located in the cluster area will be contacted too. This applies in particular to those regions that have qualified as "hydrogen valley". The cluster coordinators are already in close technical contact with Roland Berger.

Besides these activities for the common specification and a joint procurement exercise of fuel cell buses the cluster members are now in the process to initiate the setting up of common specifications for hydrogen refueling stations.

According to NOW, a second call within NIP II on the topic “Fuel Cell Buses” will be launched in early 2018. Here, the cluster coordinators cooperate with NOW to ensure that this call will be designed in terms of time and content that the necessary basic decisions at the transport companies have already been made.

3.5 Northern Europe cluster

3.5.1 Overview of activities to date

Summary

Fuel cell bus deployment project development activities in the Northern Europe cluster span an area including Denmark, Norway, Sweden, Finland, Estonia, Latvia, Poland and the Czech Republic. The Latvian Academy of Sciences led the Northern Europe cluster throughout 2016/17 and spread knowledge of fuel cell vehicle deployment possibilities and necessary infrastructure for real-life usage. The cluster coordinator also led a working group between the cities involved in the Northern Europe cluster to develop an approach to joint procurement. However, achieving the original ambition to establish a joint procurement approach encompassing all cities / regions in the cluster is fraught with difficulties arising from a combination of factors. These include differences in legal frameworks, languages, ownership arrangements, commercial structures, technical requirements, readiness to deploy fuel cell buses and levels of commitment to such projects between the different cities.

Despite the best efforts of all involved, the working group concluded that it would be challenging or even impossible proceed with joint procurement of fuel cell buses. Rather than undertaking a formal joint procurement exercise, a more pragmatic approach is expected to involve several parallel procurements by cities from across the region based on a technical specification for fuel cell buses that is standardised as far as possible and on a coordinated timeframe. The other option that remains available is for cities in the Northern Europe cluster to join the procurement exercises in either the UK or German / Italian clusters. The UK joint procurement framework in particular provides a good opportunity for this type of approach as it has been specifically designed to allow public and private sector organisations from across Europe to place orders for buses under similar terms.

Details of cluster coordination in Northern Europe and potential demands for FC buses

The cluster coordinator has continued to work closely on a zero-emission bus development programme with other partners from across the region, including:

- Vatgas (Hydrogen Sweden) in Sweden;
- OREEC Oslo Renewable Energy and Environment Cluster in Norway;
- Czech hydrogen platform in Czech Republic;
- Tallinn linetransporti TLT and Alexela Group OU in Estonia;
- NyOrka ehf (Icelandic new energy Ltd.) in Reykjavik (Iceland);
- Institute of Power Engineering in Poland.

The table below summarises the fuel cell bus deployment plans in the region. Note that the list includes also cities from “EU Hydrogen Regions & Cities” (Oslo, Norway; Trutnov, Czech Republic; Sofia, Bulgaria; Velenje, Slovenia), that are evaluating the existing public transport fleets and operational needs for fuel cell bus deployment. These cities do not yet have firm plans (hence no figures for number of buses are given in the table), but are investigating possible funding sources beyond the JIVE project(s).

City	No. of FC buses				Total for pre-2020 projects	
	Projects beginning in 2017/18		Future projects			
	12m	18m	12m	18m	12m	18m
Riga, Latvia	10			20	10	20
Other Latvian cities			10		10	
Tallinn, Estonia			10		10	
Herning Denmark	10				10	
Kolding, Denmark	10				10	
Akershus, Norway	10		10		20	
Bergen, Norway			5		5	
Reykjavik, Iceland	5				5	
Gävleborg, Sweden	5				5	
Helsinki, Finland			10		10	
Warsaw, Poland			10		10	
Velenje, Slovenia						
Sofia, Bulgaria						
Trutnov, Czech Republic						
Oslo, Norway						
TOTAL	**50**	**0**	**55**	**20**	**105**	**20**

The following table gives further details of the context in which demand for fuel cell buses exists in the Northern Europe cluster cities.

City	Population (approx.)	Bus fleet size	Primary operator(s)	No. of bus HRS
Riga	696,000 (2015)	430	RM LLC Rigas Satiksme	One (under development, project H2NODES)
Parnu	39,000 (2016)	12	GoBUS	One (under development, project H2NODES)
Helsinki	629,512 (2016)	-*	Nobina Finland; Veolia Transport Finland; Helsingin Bussiliikenne.	None

Kolding	57,583 (2013)	22	Sydtrafik (PTA);	One (350bar dispenser to be deployed)
Akershus	573,326 (2014)	-*	Ruter AS	One
Bergen	278,121 (2016)	-*	Skyss	None
Reykjavik	32,330 (2015)	109	Stræto bs	One
Gavleborg	276,323 (2011)	-*	VS & Persson; Nettbuss	One
Warsaw	1,748,916 (2016)	1,800	MZA; Mobilis, ITS Michalczewski PKS	None
Oslo	658,390 (2016)	-*	Ruter AS	One

**information not available*

All the cities / regions mentioned above have started preliminary evaluation of fuel cell bus deployment and are willing to participate in the Northern Europe cluster. Some cities have already identified the source of hydrogen supply (see table above) and in some cases, it is intended to install the necessary 350 bar dispenser and auxiliary units to meet the needs of fuel cell buses in cases of deployment. Given the different PTO arrangements (outsourced / municipal etc.) in the different cities, the final technical specification and awarding processes will be the responsibility of each of the deployment partners.

Overview of selected local projects

Riga, Latvia

Zero emission public transport is a high priority for Latvia's capital city. There are strong political contributions with the aim to deploy zero emission transport (including the construction of a new tram line and fuel cell buses). Riga City Council announced that the aim is to deploy around 240 fuel cell buses in Riga from 2020 and to deploy all these vehicles within three years to meet the requirement of existing bus fleet replacement. To implement the foreseen plan, Riga is working with stakeholders in Sweden and Denmark to establish an application for the Connecting Europe Facility blending call to help finance this ambitious project. The intention is that the large number of fuel cell buses will be leased. Riga is an active member of the established Baltic Sea Region hydrogen network partnership that combines stakeholders around the Baltic Sea region for the further development of hydrogen applications. This forum provides the opportunity for Riga to share its experience with other interested cities and to collaborate with other experts on developing the next phase of fuel cell bus roll-out in the region.

Gävleborg, Sweden

Sustainable development is a high priority issue for Region Gävleborg. There is a strong political will to contribute to the targets set both in the Europe 2020 strategy and in the EU 2030 Framework for climate and energy. The county of Gävleborg consists of ten municipalities, 280,000 inhabitants and covers an area of 18,200 square kilometres. The biggest municipality is Gävle which recently reached 100,000 inhabitants. The neighbour

Sandviken is the second biggest with 40,000 inhabitants, of which 25,000 live in the city of Sandviken.

The city of Sandviken has a poor public transport city route network. However, there is a comprehensive plan to replace the network between the years 2019–2020, with a more efficient and more attractive route network. Compared to other cities in the county there is a great potential to double or even triple the number of trips taken using public transport in Sandviken. The aim is to announce a public procurement for 5 fuel cell buses. The buses will be refuelled at the existing public HRS at Sätravägen 17 in Sandviken. This station is supplied by hydrogen fed from a pipeline at a nearby steel factory, which uses 100% renewable energy mainly originating from a local onshore wind farm which is the biggest in Scandinavia.

Beyond bus applications, the municipality of Sandviken is interested in broadening the use of fuel cells to include garbage trucks. Sandvik Group is interested in using big forklifts at their industry facility in Sandviken. Also, in 2016 the first electrified public road was in inaugurated a few kilometres west of Sandviken. The trucks are diesel-electric hybrids from Scania. Scania is interested in replacing the diesel engine with fuel cells to make these trucks fully electric.

Reykjavik, Iceland

Reykjavik is fully committed to a sustainable urban mobility transport plan – SUMP – and is investing significantly in its transport infrastructure so that it encourages and facilitates multi modal transport choices.

The public transport company that operates buses in Reykjavik and the surrounding area (Straeto bs) has purchased four proof of concept battery electric buses and has two methane buses already in service. The goal of the company is to run the entire fleet of 120 buses on eco-friendly fuel by 2040. To do this, renewable energy sources will be used to power a green fleet of battery buses where appropriate, but with hydrogen fuel cell buses on the other lines. With the support of the FCH JU and strategic stakeholders, Straeto bs plans to deploy five fuel cell buses in 2019 to operate in the city centre, aiming to make almost 15% of the bus fleet eco-friendly by 2020.

The construction of a hydrogen refuelling station with on-site production is already being planned in the vicinity of Straeto's bus depot. The operator of the station has agreed to triple the capacity of the station and dispense both 700 bar and 350 bar hydrogen so that all of the buses can be refuelled with renewable hydrogen. The cost of upgrading the station will be covered by the current operator (Skeljungur).

Joint procurement process

Background

In its role as a partner in the JIVE project, Riga (Latvia) Municipality limited liability company "Rigas Satiksme" launched a public procurement in October 2016. This procurement exercise sought ten fuel cell buses (12m) as part of the JIVE project and ten fuel cell range extended trolleybuses as part of the Action "H2Nodes – evolution of a European hydrogen refuelling station network by mobilising the local demand and value chains" funded by Connecting Europe Facility. Due to the offered high price of the FC bus unit, the contract (procurement) has been awarded only for the FC-range extended trolleybuses. To solve the high price issue about the FC buses, Rigas Satiksme requested a new offer in the middle of 2017. Meanwhile, Riga city council announced that the aim of public transport in Riga is to deploy 240 zero emission buses as part of a bus replacement strategy. Of this figure, 200 are expected to be fuel cell electric buses. As of the end of 2017 the new offer for fuel cell buses had not been received. In mid-February 2018, Riga city council and Rigas Satiksme will decide whether to cancel the existing procurement and to prepare a new one. Due to legal issues, Rigas Satiksme cannot discuss the technical specification for the vehicles with third parties until after this procurement decision has been made.

Approach to joint procurement

The Northern Europe cluster partners recognise the benefits of developing a common technical specification for fuel cell electric buses that would be included in all of the procurements. Thus due to the fact that each city/region will announce a procurement, the specific requirements that apply for the city/region, must be included in the technical specification. The technical specification was developed based on the Rigas Satiksme technical specification used for the procurement back in 2016, also taking lessons from the technical specifications used in the UK and German joint procurement exercises. The approach is to agree a common overall technical specification and afterwards to give a time for the city / region to customize the overall technical specification to the requirements of operators in each city / region.

In the absence of a final decision by Rigas Satiksme regarding procurement of fuel cell buses, each city / region agreed to start to develop their own tender exercises. The coordinated way of “a number of procurements” speeded up the internal discussions due to the fact that the “usual way” of each city / region will be applied for the procurement. As aa result, there will be different types of procurements around the region with common technical requirements included in the technical specifications. To reach the set price goal per FC bus unit, it is necessary that all the procurements are announced in the same time period (i.e. Q3 of 2018).

The timescales for the fuel cell bus procurement activities in the Northern Europe cluster are summarised below.

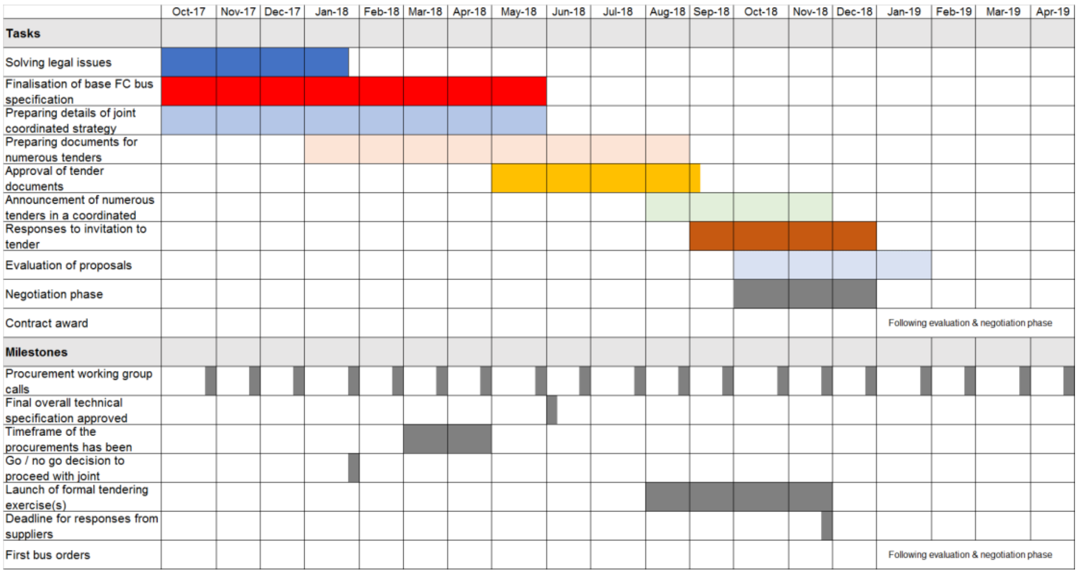


Figure 21: Overview of timescales for procurements of fuel cell buses in the Northern Europe cluster

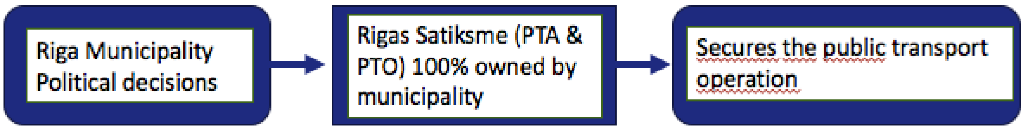
With the support of the Latvian Academy of Sciences, the city of Riga is leading on developing the coordinated approach, working closely with other cities in the cluster. Other

Northern Europe cluster cities are free to join the development process of the technical specification.

Models for delivering public transport in cities in the Northern Europe cluster

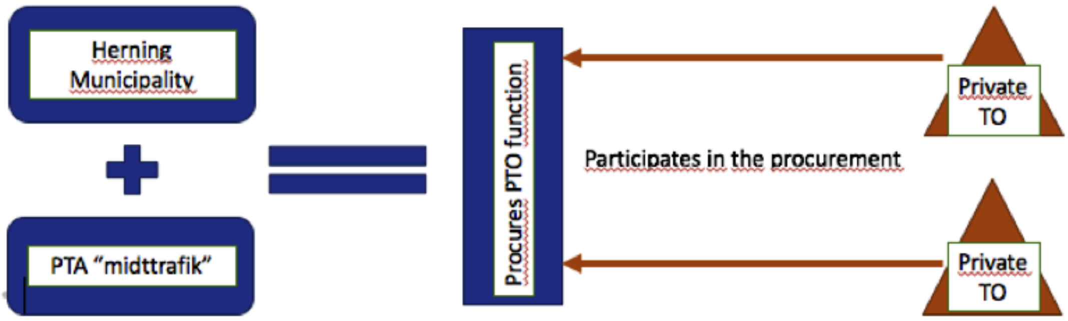
Within the Northern Europe cluster region two types of PTO arrangements exist:

1. The PTO is owned by the municipality (local public entity), as is the case in Riga:



In Riga, Latvia, the PTA and PTO is the same body. Taking into account that the Rigas Satiksme is 100% owned by the municipality, and has granted an exclusive right to secure the public transportation in the Riga City area, Rigas Satiksme can freely participate in the joint procurement, because there is no possibility that the buses are funded for a private company and afterwards the company does not have the rights to secure public transportation function in the area.

2. The PTO is not a local public entity – this is the situation in Herning (Denmark):



In Herning, the local municipality together with the PTA "midttrafik" prepares the technical specification for bus services after discussions with private bus operators. The municipality then procures the public transport operation as a service, and the private transport operators compete to become the next public transport operator for a set time (8 years with a possible extension for 4 years). The awarded PTO secures the public transport function (transportation for the public transport routes) with their own vehicles and the payment is on a per operational hour basis. The next procurement for the PTO in Herning (Denmark) will be announced in early 2018 and conclude by the end of 2018.

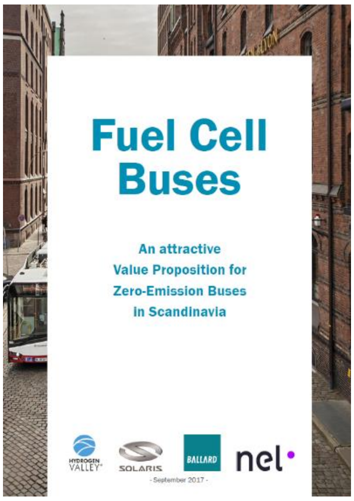
The same PTO arrangement is used in different cities around the Northern Europe cluster territory i.e. Parnu, Estonia, where the contract for public transport operator is awarded for 5 years and the payment is calculated per kilometre. Also in Parnu, the private operator secures the public transport function (transportation for the public transport routes) with their own vehicles. In Gavleborg region, Sweden, the public transport operator is awarded for 10 years and the payment is calculated per kilometre and operational hours (combined calculation). In Gavleborg region it takes around 2–3 years from the start of the procurement exercise to award the new PTO until the start of operation. The start for the next procurement is set from the beginning of 2018, so that the new PTO could start to operate from 2020. The municipality of Gavleborg region is evaluating possible exceptions to secure zero-emission bus deployment, whereas the municipality as a body could participate in the joint procurement and afterwards hand over the rights of usage for the new PTO.

The different contractual and ownership models for delivering public transport in cities in the Northern Europe cluster was the main issue to agree with the "coordinated" procurement approach.

Initiating individual procurement processes in parallel (i.e. in a coordinated way) could speed up the overall approach of JIVE. However, many of the cities and regions in this area, especially in Eastern Europe, are not willing to strongly commit due to the lack of funding options and number of hydrogen applications in the region. Involvement of new cities in Northern Europe has stopped until the results of Riga will be achieved and the "visible" results can be shared together with experience.

3.5.2 Plans for fuel cell bus deployment beyond funded projects

In addition to supporting the development of fuel cell bus demonstration projects in selected cities, the cluster coordination work undertaken in Northern / Eastern Europe helped to catalyse wider interest in the potential of this technology and led to some industry representatives setting out a vision for fuel cell bus roll-out on a commercial basis in Scandinavia. In September 2017 a group of companies including Solaris, Ballard, and Nel Hydrogen, organised a fuel cell bus event in Copenhagen at which a commercial offer for fuel cell buses including the necessary framework (quantity, continuous demand) was presented. The overall offer is summarised in the "*Fuel Cell Buses: An attractive value proposition for zero-emission buses in Scandinavia*" paper, which refers to a bus price of €450k for orders of 100+ vehicles per year. At this price and with competitive maintenance cost (€0.35/km) and fuel costs (€5/kg, 7kg/100km), the authors argue that the fuel cell bus offers lower ownership costs than battery electric buses, as shown in the graph below (from Ballard).



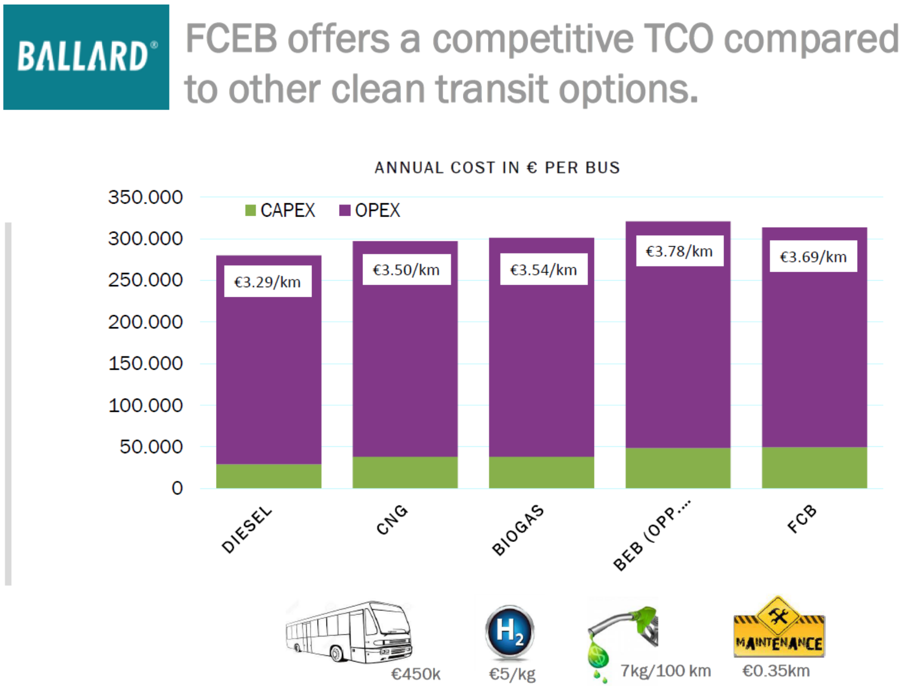


Figure 22: Ownership cost analysis for buses with different drivetrains (source: Ballard)

The presentation from Nel at the Copenhagen event suggests an even more bullish forecast of the future costs (prices) of fuel cell buses, suggesting that at 20,000 buses deployed the fuel cell option will compete with diesel buses without subsidy.

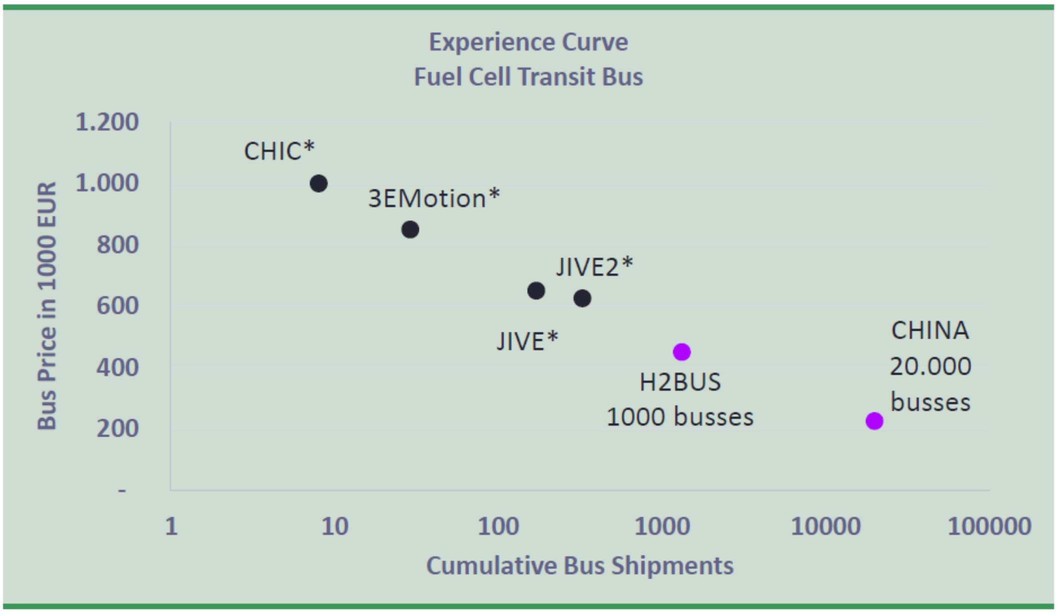


Figure 23: Projected price of fuel cell buses as a function of cumulative shipments (source: Nel)

Delivering lower cost fuel cell buses and cost-effective hydrogen supplies will require roll-out at an even larger scale than that planned in JIVE / JIVE 2. Whereas these projects will lead to joint orders for many tens of vehicles, deployment on a commercial basis is expected to require sustained orders of hundreds of buses per year (total demand of thousands of buses). The strategies for joint procurement initiative has provided a good basis for unlocking this scale by coordinating the demand and supply sides, although some concerns exist relating to the relatively limited number of responses to the joint tender exercises run in the UK and Germany in 2017.

3.5.3 Planned next steps

Further steps for wider alternative fuel implementation include:

- **Finalisation of common technical specification.** The Northern Europe cluster coordinator has engaged with the German and UK cluster coordinators to develop a common technical specification that will determine the overall figures and requirements for the participant cities in Northern Europe cluster. Due to the legal issues based on the different arrangements of PTOs around the Northern Europe cluster territory, it is clear that "coordinated" approach will be taken, thus it is not precisely which cities / regions will participate and involve in the timeframe determination for the fuel cell bus procurements. The common technical specification is therefore not yet finalised. However, the specification is available to all interested cities / operators for use in the event of bus procurement being carried out via a series of coordinated (individual) tenders.
- **Engage with other cities with updated information on fuel cell buses**. After a wide dissemination of real-life deployment results, it is expected that even more cities will evaluate FC vehicle deployment possibilities. The aim will be to disseminate the most up to date information and to stimulate further demand for these vehicles. In the December 2017 a Baltic Sea Region Hydrogen network (BSRHN) was established with an aim of further hydrogen application implementation in the Region. As one of the aims of the (BSRHN) is to seek other funding possibilities for the fuel cell bus deployment within the Region.
- **Approval of legal framework for procurements**. As part of the development of the procurement strategy. Launch of a formal tendering processes will be contingent on obtaining the necessary approvals from a legal perspective. Additional agreement about the timeframe of the procurements is necessary for further steps.
- **Collaboration.** The Northern Europe cluster coordinator will identify possibilities speed up the agreement about the timeframe of coordinated procurements.
- **Further involvement.** Continuous work with observer cities to identify hydrogen supply for the possible fuel cell bus deployment. Preliminary evaluation of the routes around the cities are still under investigation, to seek the best possible cases for the fuel cell bus deployment.

3.6 UK cluster

3.6.1 Introduction

The main activities undertaken by UK cluster coordinator in this project included:

- Supporting the cities involved in the JIVE projects with developing and delivering the joint procurement exercise for fuel cell buses.
- Facilitating exchange of information between the cities with well-developed fuel cell bus deployment plans, and outreach to other city and bus operator representatives to inform a wide audience of the developments in this sector.
- Working with bus / hydrogen industry representatives, and with bus operators, to develop plans for introducing fuel cell buses at a larger scale in the post-2020 period.

The remainder of this section summarises the progress made to date in each of these areas.

3.6.2 Joint procurement of fuel cell buses

Overview and status as of early 2018

The formal procurement exercise to establish a framework for supply of fuel cell buses in the UK cluster was initiated in late April 2017.[24] The latest timetable for this exercise is shown below. Note that the overall programme and milestone dates have been revised relative to those initially indicated in the procurement documents; for example the deadline for responses to the ITN was moved back to give suppliers more time to respond (as this period fell within the summer factory shutdowns that many bus OEMs implement). Also, the negotiation period is significantly longer than originally anticipated, partly a result of the complexity of one lead authority negotiating with suppliers on behalf of multiple potential customers for the vehicles, and partly due to the need to finalise as many details as possible before the procurement framework is established.

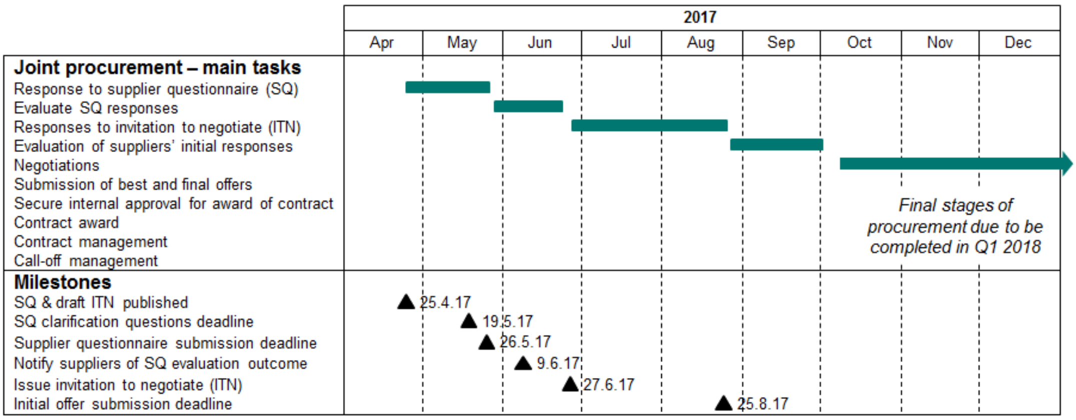


Figure 24: Timescales for joint procurement of FC buses in the UK cluster

As of early 2018, the intention remains to establish a framework that will be in place for up to four years and that will allow joint procurement of fuel cell buses by multiple cities / operators in the UK and other European countries. Transport for London is leading the procurement exercise and is currently holding negotiations with potential suppliers.

The mechanism for placing orders for buses will either be via direct award to a selected supplier or via "call offs" – i.e. mini competitions between suppliers on the framework in response to orders for a set number of vehicles. The timing of these competitions (and hence timing of vehicle orders being placed) depends on several related factors such as each bus customer securing the necessary approvals to proceed with committing to ordering the vehicles. Given the importance of coordinating bus orders to ensure that economies of scale are maximised, the group of UK cities planning the first deployments under the JIVE project has agreed to place a joint order by the end of March 2018. The same framework is expected to be used by other cities participating in JIVE 2, and potentially by other cities / bus operators with their own fuel cell bus implementation plans.

[24] The OJEU notice is published here: http://ted.europa.eu/udl?uri=TED:NOTICE:157506-2017:TEXT:EN:HTML&src=0.

Further information relating to the process followed to establish the joint procurement approach in the UK is provided in the form of a case study (see section 8.1.1), the lessons from which are repeated below.

Joint procurement – lessons learnt

The joint procurement exercise outlined above is on-going as of early 2018 and although the framework is close to being established, the first order for buses is yet to occur. Nevertheless, this approach to joint procurement is expected to lead to a successful result as multiple suppliers have confirmed their ability to offer vehicles that meet the required technical and commercial conditions. The following lessons can be drawn from the experience to date:

Overall approach to procurement

- One concept considered early in the process was based on selecting a preferred bus supplier before acquiring funding for the buses (from the FCH JU and other sources), and then entering into firm contracts for bus supply. The idea was that by working with a preferred supplier, applications for grant funding would be strengthened. However, the procurement working group concluded that it would be preferable to avoid committing to one supplier too early and that keeping options open would ultimately lead to greater competition and hence more attractive offers.
- An early conclusion of the procurement working group was that it is necessary to run a fully compliant procurement exercise for the buses given that (some of) the expected customers are public sector organisations.
- At one stage the group considered giving the lead role on procurement to a private sector bus operator, who could also conduct a compliant procurement exercise. The rationale for this concept is that large private operators purchase hundreds of buses per annum and are therefore well placed to use their purchasing power to achieve more attractive commercial terms. The group decided that on balance it was preferable to retain control over the process within the public sector bodies that are driving the fuel cell bus deployment initiative.
- The level of resource required to run a joint procurement exercise of this type should not be underestimated. There is a need for procurement experts, technical input (e.g. writing specifications), and legal advice as per any standard procurement for vehicles. In addition, time needs to be budgeted for coordinating between multiple councils / authorities and collecting input from a broad range of stakeholders (e.g. details of how bus specifications vary by city).
- The group also considered the option of jointly procuring hydrogen refuelling stations / hydrogen supplies, but concluded that given (a) the differing requirements in different locations and (b) the limited scope for economies of scale effects to reduce costs, it is more appropriate for cities to develop their own refuelling infrastructure plans.

Procurement process and timescales

- There is a need for a procurement strategy document that sets out the terms of reference for the group and responsibilities of all involved. Creation and agreement of such a document is generally the first step in any procurement process.
- It will have taken over three years from initially considering options for joint procurement to the first orders of buses. This is far longer than originally envisaged and not a timescale that others embarking on a similar exercise should seek to

replicate. Delays occurred at various stages in the process and for many different reasons. For example, there was a change to the lead authority after the initial phase of work. There were also delays in issuing tender documents due to factors beyond the control of the core project team.[25] Following the launch of the formal procurement exercise, the timescales had to be revised to account for constraints faced by the potential suppliers (e.g. summer factory shutdowns, availability of appropriate representatives to attend negotiation discussions).

- While delays in the procurement process caused some frustration amongst parties seeking to deploy the zero emission buses as soon as possible, there were some advantages to the extended timescale. For example, there was more time for the potential suppliers to develop their products and improve their offers, an important factor in a market such as this where one of the aims was to encourage new suppliers to offer new products. The delays also provided additional time for the cities to secure all the funding necessary to commit to purchasing fleets of fuel cell buses and to progress with plans for refuelling infrastructure deployment.
- One of the important factors behind the success of this exercise has been early market engagement. Dialogue with potential suppliers was initiated early in the process and proved useful for informing suppliers of the emerging opportunity while allowing the buyers to tailor the process to maximise the chances of a desirable outcome.

3.6.3 Cluster management and demand for fuel cell buses

Overview

Throughout this project Element Energy continued to work closely with the cities planning deployment of fuel cell buses as part of the JIVE programme. This involved facilitating discussions between key parties (e.g. infrastructure providers, landlords, and energy suppliers), reviewing procurement documents, chairing regular procurement working group calls / meetings, and facilitating information exchange between the cities.

During the early phase of this project the focus was on supporting cities with advanced plans to purchase new fuel cell buses. Once the joint procurement exercise was well underway, the UK cluster coordinator contacted the wider group of cities that have expressed interest in fuel cell buses to update them on progress in the sector. A meeting of the UK cluster was held in late October 2017, which provided an opportunity to discuss details of the deployment plans in the JIVE and JIVE 2 projects, update a wider group of cities on the latest plans and status of the sector, and present the emerging conclusions from the work Element Energy undertook on planning further roll-out beyond the subsidised phase (see following sub-section).

[25] For example, shortly before the planned ITN publication date (the point at which the tender documents, including the draft contract, were published), concerns over certain details in the draft contract were raised by legal experts reviewing the documents. Due to exceptionally high workload (from other areas of the business), the process of refining these details took several weeks.

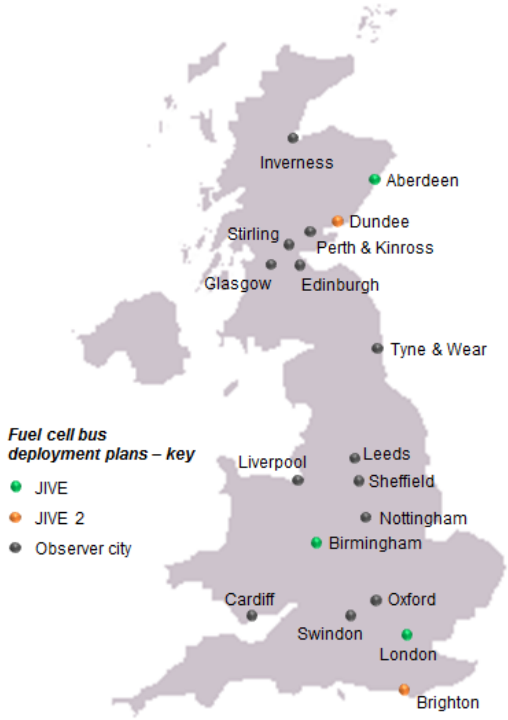


Figure 25: Cities involved in the UK cluster during the 2016/17 cluster coordination project

Further details of the context in which demand for fuel cell buses exists in the UK cities with firm deployment plans are given in the following table.

City	Population (approx.)[26]	Bus fleet size	Primary operator(s)	No. of bus HRS
Aberdeen	230,000 (2016)	c.300[27]	First Aberdeen Stagecoach	One (Kitty Brewster)
Birmingham	1,101,000 (2016)	c.1,500	National Express	None (one planned in JIVE)
Brighton	277,000 (2016)	c.270	Brighton & Hove Buses	None (one planned in JIVE 2)
Dundee	150,000 (2016)	c.110 (Xplore Dundee)[28]	National Express (Xplore Dundee)	None (one planned in JIVE 2)
London	8,700,000 (2016)	c.9,500[29]	>10 operators	One (Temple Mills), second planned in JIVE

[26] Based on estimates from http://ukpopulation2016.com/.
[27] Includes 160 First Aberdeen buses (www.firstgroup.com/aberdeen/about-us) and a similar number of Stagecoach buses (Stagecoach North Scotland have a fleet of c.380 vehicles covering Aberdeen city, Aberdeenshire, Buchan, Moray, Inverness, Badenoch and Strathspey, Caithness, Easter Ross, Sutherland, Orkney and Skye – see www.stagecoachbus.com/about/north-scotland#tab1).
[28] http://www.nationalexpressgroup.com/newsmedia/business-facts-and-figures/
[29] https://tfl.gov.uk/corporate/publications-and-reports/bus-fleet-data-and-audits.

Additional information on cities with near-term fuel cell bus deployment plans

The JIVE and JIVE 2 projects are supporting a total of five local fuel cell bus projects in UK cities. Further information on the context of these initiatives is given below.

Aberdeen

Aberdeen has an existing fleet of ten fuel cell buses. The adopted Hydrogen Strategy[30] (2015–2025) includes an ambition for at least 15 more and the Council has approval to procure up to an additional 20 vehicles as part of the JIVE / JIVE 2 projects (although based on current plans the funding will only support 10 more buses). In early 2018, Aberdeen City Council published a prior information notice to announce a market test into the feasibility of procuring renewable hydrogen supplies for the cities of Aberdeen and Dundee.[31] The market sounding questionnaire explains the vision to procure renewable hydrogen supplies totalling 1,300 kg/day from 2019 (900 kg/day for Aberdeen, 400 kg/day for Dundee) to support the roll-out plans for hydrogen-fuelled buses and other vehicles in both cities.

Birmingham

Like many large cities, Birmingham faces challenges in complying with air quality targets and a review of air quality across the city led to Birmingham City Council to declare the whole borough an Air Quality Management Area (AQMA) in January 2003. As part of a strategy to address poor air quality, a new *Clean Air Zone* will be introduced in Birmingham by 2020. The most polluting vehicles such as buses, taxis, coaches and lorries will be discouraged from driving in the zone via a series of charges. In this context, Birmingham City Council has been developing plans to deploy a fleet of at least 20 fuel cell buses in the city from 2019. These buses will be procured via the joint procurement framework established and managed by Transport for London on behalf of all cities in the UK cluster. This first fleet of 20 buses will be supported by the JIVE project. Subject to a successful demonstration, there is significant potential to increase the fleet of fuel cell buses operating in Birmingham (as shown in the table above, the total bus fleet size is c.1,500 vehicles), both on conventional routes and potentially as part of innovative transport solutions such as the *Sprint* buses planned for delivery by the mid-2020s (the "Sprint Network" includes seven routes that are part of the HS2 connectivity package).[32]

Brighton

Brighton & Hove's Air Quality Management Area has one of the highest population densities in the UK at close to ten thousand people per square kilometre. The poor local air quality is mainly due to road traffic and as part of the City Sustainability Action Plan, the Council has committed to *use new technology to maximise reduction of carbon emissions*.[33] The main bus operator in the city (Brighton & Hove Buses, part of the Go-Ahead group) is a partner in the JIVE 2 project and is seeking to deploy a fleet of at least 20 fuel cell buses to replace diesel vehicles in its day-to-day operations. Brighton & Hove Bus and Coach Company operate most of the bus services throughout the city of Brighton & Hove with a fleet of circa 270 buses from four bus garages. The company also operates a further 140 buses from a garage in Crawley under the Metrobus brand which provides most of the local services throughout Crawley Town, Gatwick Airport and several rural services in the surrounding towns and villages. Brighton & Hove Buses is participating in the JIVE 2 project in order to

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30 www.aberdeeninvestlivevisit.co.uk/H2-Aberdeen/H2-Aberdeen-Resources.aspx
31 www.publiccontractsscotland.gov.uk/search/show/search_view.aspx?ID=FEB308982.
32 See www.tfwm.org.uk/development/sprint/.
33 Brighton's City Sustainability Action Plan, p.15 (2015). www.brighton-hove.gov.uk/content/environment/sustainability-city/city-sustainability-action-plan.

demonstrate and validate the real-world performance of fuel cell buses. Subject to a successful initial trial and the predicted cost reductions being realised, the company is interested in expanding the fleet of zero emission fuel cell buses as a key part of the strategy to reduce harmful emissions and improve air quality in the areas in which it operates.

Dundee

Dundee is currently undergoing one of the most active regeneration projects in the UK. A total of £1 billion is being invested to re-integrate Dundee's central waterfront area with the city centre over a thirty year period from 2001. Dundee City Council faces the challenge of managing this growth while also targeting important improvements in air quality. The Council has assigned an Air Quality Management Area covering the entire city as a result of exceeding air quality limits for nitrogen dioxide and particulate matter that mainly originate from road traffic. Dundee City Council is a partner in the JIVE 2 project and plans to introduce an initial fleet of 12 fuel cell buses to the city. The Council considers the deployment of hydrogen fuel cell buses to be an important part of the city's strategy to reducing harmful emissions at key emission hot spots and will continue to seek opportunity to build on the foundations laid by the JIVE 2 initiative.

London

Like many major cities, London faces significant challenges associated with meeting increasing demands for public transport (London's population is forecast to grow from around 8.7 million today to >10 million by 2030) while addressing local air quality issues and wider environmental concerns. London has recognised the need to reduce the environmental impact of public transport as far as possible and a transition to low emission buses is now underway.[34] In the short term this mainly involves improving the performance of diesel buses and implementing hybrid diesel-electric vehicles. However, to comply with medium to long-term targets (such as the strict requirements of the *Ultra Low Emission Zone* being introduced by 2020), fully zero emission vehicles will be required. London has a fleet of ten fuel cell buses (eight from the CHIC project and two recently delivered via the 3Emotion project). Transport for London is a partner in the JIVE project and is working on introducing a new fleet of up to 26 fuel cell buses through this initiative. This is consistent with the Mayor's commitment to phasing out diesel buses over the coming years.[35]

Other UK cities with an interest in fuel cell buses

Although many different cities / regions were contacted as part of the cluster coordination process, most are yet to develop firm plans to introduce fuel cell buses. With the exception of London (where services are regulated by the transport authority (TfL)), most bus services in the UK are currently deregulated; i.e. private bus operators can decide which buses to run, on which routes, and with what frequency. However, the Bus Services Act 2017 (which mainly applies in England) gives powers to local transport authorities to introduce franchising or new partnership arrangements in certain areas.[36] For example, the mayors of the six regional combined authorities created in May 2017 are empowered to create bus franchises

[34] For example, the Mayor's Transport Strategy published in summer 2017 included a proposal to ensure that all new single deck buses in London are zero emission from 2020 and that this policy is extended to double deck buses in 2025.
[35] www.london.gov.uk/press-releases/mayoral/sadiq-to-stop-buying-dirtiest-diesel-buses. https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/the-mayors-transport-strategy.
[36] http://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-7545.

(akin to the model used in London).[37] It is not yet clear which (if any) of these areas will use these powers. This legislative change is relevant for the zero emission bus market as the local / regional authorities with powers under the Bus Services Act could stipulate minimum emission standards for buses in their areas.

The consensus amongst the most active cities in the UK cluster was that significant value resulted from working together in a coordinated way and that some form of on-going coordination to develop more ambitious deployment plans would be beneficial. Given that the economics of operating fuel cell bus fleets improve with scale, and that a premium over diesel buses is expected to remain for the foreseeable future, the most likely route to increasing the number of such vehicles in the UK is expansion in the "JIVE cities", particularly London given the proposed policy to only purchase zero emission buses from 2025 (and potentially in cities introducing Clean Air Zones – see below).

Clean Air Zones – overview

In an attempt to comply with air quality standards, the UK Government has mandated the introduction of Clean Air Zones in five cities: Birmingham, Derby, Leeds, Nottingham, and Southampton. These zones are expected to be implemented by 2019/20.

London has its own air quality strategy and plans to phase out the purchase of diesel buses such that all new buses introduced from 2025 are zero emission.

Various cities are putting pressure on the Government to take firmer action – e.g. the leaders of Liverpool, Leeds, Birmingham, Southampton, Leicester and Oxford city councils wrote to the Environment Secretary following the 2017 consultation on improving air quality calling for urgent legislation and a proper diesel scrappage scheme.

UK cities developing plans for Clean Air Zones (or equivalent)

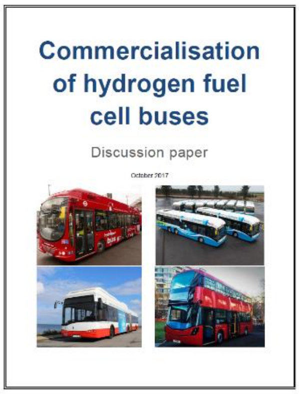
[37] On 4 May 2017 six regions of England held elections for newly created combined authority mayors: Tees Valley; Greater Manchester; Liverpool City Region; West Midlands; Cambridgeshire & Peterborough, and the West of England.

3.6.4 Planning beyond the subsidised phase

Context and White Paper on commercialisation of fuel cell buses

Many cities / regions across Europe are implementing plans to phase out diesel buses (and other vehicles) over the coming decades, which means that fuel cell buses will need to compete with other zero emission options, principally the battery electric bus.

In this context, Element Energy investigated options for larger-scale roll-out of fuel cell buses from the early 2020s, i.e. following the next wave of technology validation and demonstration activities in the JIVE programme and related projects. To do this, we held dedicated discussions with leading cities and selected industry representatives (vehicle and infrastructure providers). For example, during June and July 2017, Element Energy held ten separate meetings with vehicle OEMs, component suppliers, infrastructure providers, public transport authorities, bus operators and others. The focus was on understanding the conditions under which suppliers would be able to offer more cost-effective fuel cell buses (and hydrogen supplies) and customers would be able to commit to purchasing larger numbers of vehicles.



The results of the supplier discussions were encouraging and provided a basis for a *White Paper* on commercialisation of fuel cell buses, which Element Energy authored in late summer 2017. The key conclusions include:

- Hydrogen fuel cell buses have been demonstrated in real-world operations over many years and are now on the cusp of a commercial breakthrough. This is not widely known beyond the fuel cell bus sector but is highly relevant for cities seeking zero emission alternatives to diesel.
- Industry projections suggest that fuel cell buses will be competitive with battery electric buses on many routes within the next three to five years.
- Interest in battery electric buses from politicians in many cities has created market conditions that will allow fuel cell buses to compete economically without public sector subsidy.
- Fuel cell buses and battery electric buses are complementary technologies as they share a high proportion of common components; the most appropriate solution depends on the local context and constraints. With long range and short refuelling times, fuel cell buses offer a zero-emission solution on a wide range of routes, including high daily mileage, hilly terrain, etc.
- Continued development of Europe's fuel cell bus sector will require (i) technology-neutral zero emission policies in cities / regions and at a national level; and (ii) coordinated action to aggregate demands for vehicles that will unlock price reductions from economy of scale effects.

The White Paper was published in autumn 2017 and discussed at a meeting of the fuel cell bus commercialisation coalition in early November.[38] In the remainder of this section we present highlights from the UK-specific findings resulting from this aspect of the project.

Zero emission bus operation – economic analysis

Understanding the expected costs of operating fleets of fuel cell buses is crucial for any bus operators or public transport authorities considering adopting these vehicles. During this study Element Energy worked closely with bus OEMs, hydrogen suppliers, and bus operators to assess the underlying economics of fuel cell bus operation and to explore the conditions under which cost-effective solutions could be available.

The most likely early markets for zero emission buses are cities / regions with policies to discourage or ban the use of diesel. London is such a city, with proposed policies from the current Mayor that will require all new single deck buses introduced from 2020 to be zero emission, and the same policy to apply to all new buses (including double deck vehicles) from 2025. This type of measure removes the diesel option for operators, who are left with a choice between battery electric and fuel cell electric buses. In this section we present results of analysis of the costs of providing bus services in London for a generic route with a peak vehicle requirement of 50 vehicles. Results are expressed as GBP per contracted mile for three bus types: diesel hybrid, battery electric, and fuel cell (FC) electric. Results for the fuel cell option are shown for buses at “niche” pricing levels (c.£500k per vehicle) and at “mass market” pricing levels (c.£350k per vehicle), which bus OEMs have indicated are achievable with sustained order volumes of around 100 units per annum. The main assumptions underpinning this analysis were validated through an iterative process of meetings with various bus OEMs and operators in London and are summarised below.

	Parameter	Assumption (baseline)	Notes
Common assumptions	Contracted mileage	2,000,000 miles/yr	Representative figure for a generic London route with a PVR of around 50 vehicles.
	Dead mileage	100k / 150k miles/yr	5% of contracted mileage (diesel / FC) / 7.5% (battery) – in practice dead mileage depends on location of depot relative to route and various other factors.
	Peak vehicle requirement	50	Assumption for a generic London route.
	No. of spare buses	5 / 8	A total fleet of 55 buses is assumed for the diesel and FC options, 58 for battery electric due to limited range of pure electric buses.
	Cost of finance	5%	Representative figure.
	Bus lifetime	14 years	Representative figure.
Bus capital costs (£)	Diesel hybrid	290k	Typical price of a London spec. diesel hybrid double deck bus.
	Battery electric	400k	Assumed price of a DD battery electric bus capable of being used as a replacement for diesel hybrid.
	Fuel cell electric	500k / 350k	Indicative prices based on current costs (small-scale orders) and at scale price indications from selected bus OEMs.
Powertrain overhaul costs (£)	Diesel hybrid	20k	Representative costs of powertrain overhauls. We assume one major overhaul is required at the mid-point of the bus lifetime.
	Battery electric	80k	
	Fuel cell electric	90k	
Fuel demands	Diesel	37.5 l/100km	Equivalent to c.7.5mpg.
	Electricity	170 kWh/100km	Total consumption including heating / cooling.
	Hydrogen	8.0 kg/100km	Total consumption including heating / cooling.
Fuel costs	Diesel	£1/litre	Based on current diesel price (ex. VAT).
	Electricity	£0.10/kWh	Typical average electricity cost. In practice the average annual tariff will depend on the ratio of peak to off-peak charging and other factors.
	Hydrogen	£5/kg	Relatively aggressive all-in hydrogen price (i.e. includes cost of infrastructure). Such prices are only likely to be available given sufficient scale and long-term certainty of demand.
Infrastructure costs	Diesel hybrid	£0	No new investment required to refuel & maintain diesel hybrid buses as this is the incumbent vehicle choice.
	Battery electric	£3.95m	Includes assumed investment of £3.5m for a grid connection sufficient for a 50 bus fleet and an average of £9k per bus for in-depot chargers. In practice, infrastructure costs are highly site specific and could be lower (or higher) than this. Infrastructure investments are assumed to be depreciated over 20 years.
	Fuel cell electric	£300k	Indicative figure for cost of upgrading workshop (e.g. fitting H_2 sensors, explosion proof lighting) to accommodate FC buses. The cost of the refuelling station is included in the hydrogen price.

[38] Available from www.element-energy.co.uk/publications/.

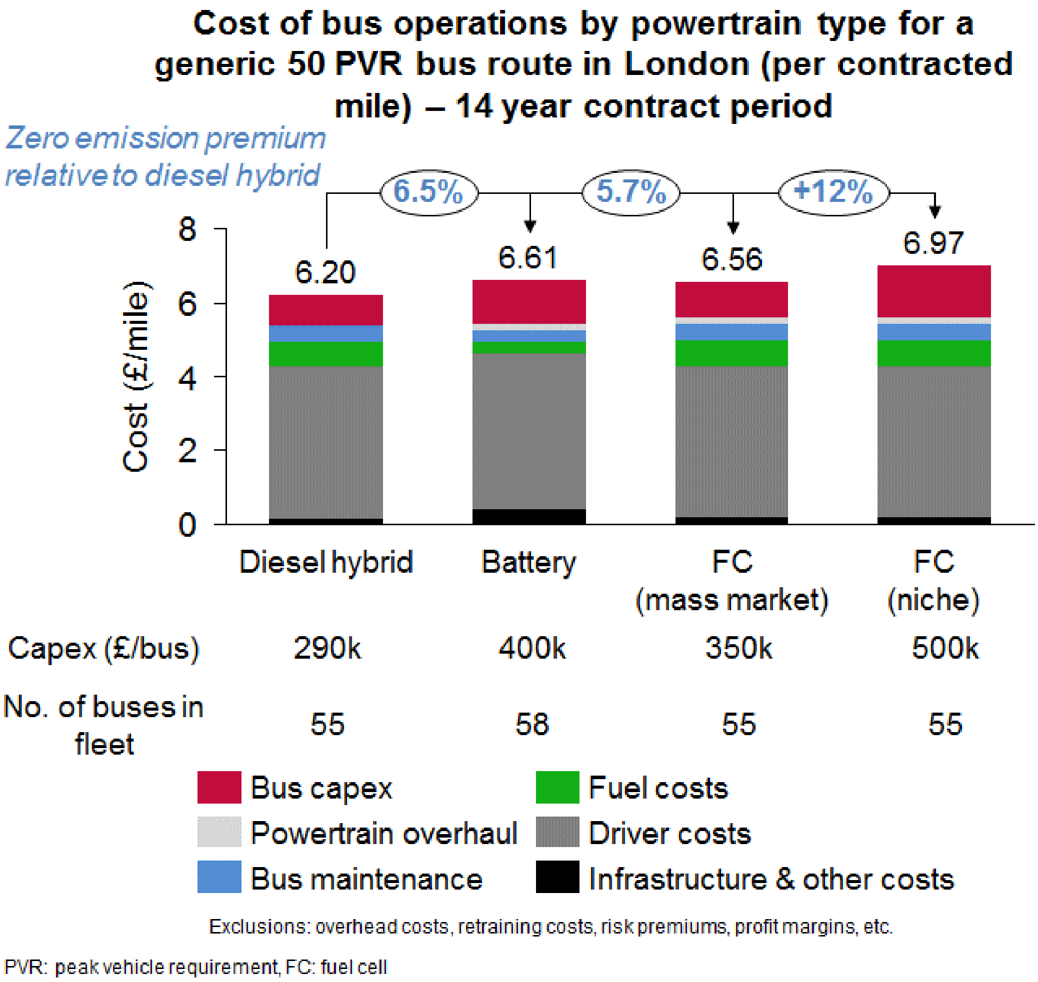


Figure 26: Results of economic analysis of providing bus services in London for a generic route of double deck vehicles over the full lifetime of buses – figures based on Element Energy analysis (not attributable to any specific bus OEM or operator)

These results suggest that (a) the overall premium for zero emission buses relative to diesel hybrid could be relative modest (<10% over the full lifetime of the vehicles), and (b) while the fuel cell option is currently the most expensive, with increasing scale this technology could offer the most cost-effective zero emission solution.

In practice, the most economically advantageous zero emission powertrain technology will depend on a wide range of factors, some of which are dictated by the local context. For example, details of the route in question, constraints at the depot at which the buses will be based, costs of new substations / upgrades to the local electricity grid. The sensitivity testing results shown below highlight the importance of key factors such as overall bus fleet size, hydrogen price, and period over which the zero emission technologies are depreciated.

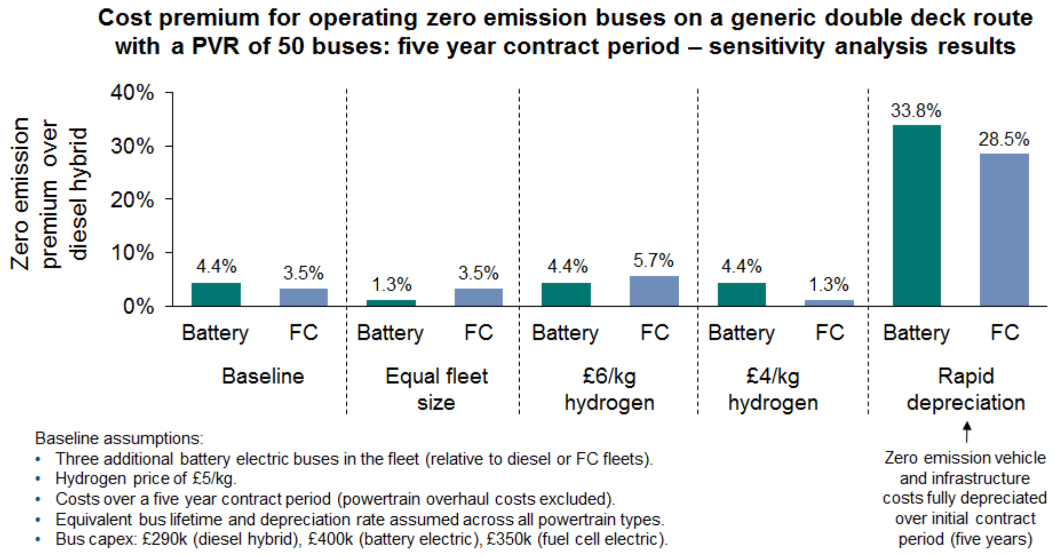


Figure 27: Effect of varying key assumptions on size of the cost premium for operating zero emission buses in London relative to diesel hybrid vehicles

The *rapid deprecation* scenario, which shows the impact of fully depreciating zero emission buses and associated infrastructure over a short period, illustrates the importance of bus operators being given confidence in the useful lifetime of new technologies. The issue of residual values of innovative technologies in this sector is explored in more detail below.

Insights from discussions with bus operators

In addition to validating the results of the economic analysis presented above, the bus operators consulted during this study provided a range of other relevant insights, including:

- When introducing a new powertrain technology for the first time, operators are likely to seek contracted maintenance services for the initial fleet of vehicles. Many operators tend to avoid retraining maintenance staff or employing new technicians until they have some experience with the new technology and confidence that it will have a long-term place in their fleets. This implies that bus OEMs offering fuel cell vehicles need to be prepared to support their products in service.
- Most bus operators typically need 12–18 months' experience with fuel cell buses before committing to increasing fleet size. The need to gain experience with new technology could limit the rate of uptake of fuel cell buses in the UK and elsewhere.
- For operational and cost reasons bus operators have a strong preference for depot-based refuelling. Non-depot-based refuelling adds *dead mileage*, i.e. distance that the buses have to travel while not in fare-paying passenger service. In terms of refuelling times, in general, ten minutes per bus is (just) acceptable, nearer five minutes per bus is preferred. Refuelling a diesel bus typically takes no more than about three minutes, which provides a target for the hydrogen industry to aim for if fuel cell buses are to be marketed as a truly zero compromise solution.
- Many bus depots are highly space constrained, which means that the footprint of any on-site refuelling infrastructure is often a concern. Low footprint hydrogen stations need to be developed and demonstrated.
- The costs of electricity grid upgrades to convert whole fleets to electric buses can be very high (and uncertain). There is also a specific issue in London related to the time taken for the local electricity grid operator to quote for new / upgraded

connections, the period for which the offer remains valid, and the timing of responding to TfL route tenders. This makes planning any solution that requires significant increases in the amount of electricity imported to the site very challenging, a factor that is relevant for proposed HRS with on-site production via electrolysis.

Barriers to further uptake of fuel cell buses and emerging solutions

The principal barriers to increased deployment of fuel cell buses in the UK to date have been linked to economics (relatively high total cost of ownership of fuel cell buses) and a lack of vehicle choice. For example, many operators' fleets are dominated by double deck vehicles and until 2016/17 there was no indication of any bus OEM being prepared to offer a fuel cell double deck bus. Furthermore, fuel cell buses are often perceived as being inefficient, unreliable, and expensive.

These issues are now being addressed, largely as a result of FCH JU-funded initiatives, namely the joint procurement ("cluster coordination") projects and the JIVE programme. Successful delivery of the local projects funded by the JIVE initiative will provide a major boost to Europe's fuel cell bus sector, further evidence of the technical performance of the latest generation of fuel cell buses, and cost reductions in preparation for wider commercial roll-out. However, several obstacles stand in the way of completing the transition to a commercial fuel cell bus sector in the UK, including:

- **Existing government support scheme for bus services** – bus services in England are provided with government support via the Bus Service Operators Grant (BSOG) system, which gives rebates to bus operators on diesel consumption (currently worth c. 35p/litre) and a per-kilometre subsidy for running bus services. The BSOG subsidy is paid directly to Transport for London to support bus services in the capital. However, outside London, this system effectively subsidises diesel use without offering any incentive for zero emission vehicles and therefore presents a major barrier to developing a commercial case for hydrogen-fuelled vehicles. The BSOG system is being reformed and one of the issues under consideration is potential "*incentive payments for low carbon emission buses*".[39] Further announcements on the BSOG reform process are expected later in 2018.
- **The challenge of achieving scale** – the economics of operating fuel cell buses improve with increasing scale due to economies of scale in vehicle supply and maintenance, and higher hydrogen demands giving opportunities for lower (per kg) cost fuel supplies. However, many bus operators new to the technology may be unwilling to commit to large fleets of many tens of vehicles before gaining some experience with fuel cell buses. Past and current publicly funded demonstration projects will address this issue to some extent, but further attention needs to be paid to this issue. Options for overcoming this barrier include focusing scale-up efforts on a relatively small number of operators with a willingness to commit to purchasing buses in relatively large numbers, and / or developing commercial offers (e.g. contracted maintenance with guaranteed service level agreements) that de-risk the proposition sufficiently that a wide range of operators will consider a more rapid progression to scale.
- **Vehicle residual values** – a combination of uncertainty over the lifetime of fuel cell buses / the key powertrain components, concerns relating to the expected high costs of replacement parts, and the fact that there is currently no second hand

[39] www.gov.uk/government/collections/bus-services-grants-and-funding.

market for fuel cell buses means that vehicle residual value (or lack of) is a major issue. For example, the standard length of route tenders in London is five years (with an optional two year extension). Diesel buses have a typical lifetime of 14+ years, which means that historically operators have been able to depreciate these vehicles over two route contract cycles. The impact of more rapid depreciation of fuel cell bus costs on the price that must be charged for providing bus services is illustrated in the chart above. There is even evidence that some leasing companies feel unable to offer bus operators a lease rate for fuel cell buses because of the high uncertainty over residual values at the end of the lease period. This issue is not unique to hydrogen buses; battery electric vehicles face a similar challenge, although to a lesser degree as the battery electric bus sector has reached a slightly higher level of maturity in recent years. It will be many years before there is a substantial evidence base on the real-world lifetimes of the latest generation fuel cell buses and similarly, the second hand market for such vehicles will not develop overnight. In the meantime, vehicle OEMs and component suppliers have a role to play in this area by providing sufficiently long-term guarantees of the performance of their products and potentially by introducing new commercial models that reduce / remove the residual value risk for bus operators.

- **Hydrogen prices** – as the sensitivity testing results above show, hydrogen price is a key factor in determining the total cost of ownership of fuel cell buses. At current diesel prices, a dispensed hydrogen price of around £5/kg or below is required for fuel cell buses to offer fuel cost parity with diesel (excluding the BSOG impact). While this figure is well below the typical targets in funded demonstration projects, several hydrogen refuelling station suppliers have indicated that prices in this range are achievable under the right conditions. Due to the nature of the investments in new infrastructure required to deliver hydrogen to fuel cell buses, two critical elements for cost-effective hydrogen supplies are: (i) scale – demands of many hundreds of kilograms per day, equivalent to a fleet of tens of buses, and (ii) certainty over future demands – hydrogen suppliers ideally required long-term contracts (e.g. ten years or more) so that capital costs can be depreciated over a long period.

None of the barriers outlined above is insurmountable and in fact work is now underway on developing new projects, mechanisms, and commercial offers designed to address most of the outstanding issues. For example, with the JIVE and JIVE 2 projects both now underway, plans for further, larger scale roll-out of fuel cell buses are under development. The next stage of the journey to commercialisation of fuel cell buses in Europe may use a combination of soft debt (e.g. from the European Investment Bank), private equity (from investors with an interest in seeing the sector develop), and a small amount of public subsidy (e.g. from the Connecting Europe Facility programme). Further explanation of this type of concept is given in the *outlook* chapter below (section 5.2).

3.6.5 Planned next steps

The activities of the UK cluster coordinator in 2016/17 have led to significant progress in advancing the fuel cell bus sector and raising awareness of the technology amongst a wide range of stakeholders. Notable achievements include:

- Progressing with the joint procurement framework that will meet the needs of all UK cities / operators participating in the JIVE projects.

- Raising the profile of hydrogen buses within the UK Government and amongst a wider group of UK stakeholders – e.g. fuel cell buses now regularly feature on the agenda of UK H_2Mobility meetings, which previously had focused exclusively on the passenger car sector.
- Articulating the conditions under which far more cost-effective fuel cell bus offers can be made and working closely with bus suppliers to help them firm up plans to bring to market attractively priced vehicles.
- Initiating a new project that is planning even larger scale roll-out of fuel cell buses in the 2020s, using novel funding, financing, and risk-sharing mechanisms.
- Elevating hydrogen on the agenda of Transport for London – as a result of the cluster coordination work, the Greater London Authority commissioned a study to examine the case and options for further roll-out of fuel cell buses in the capital beyond 2020. This provided the opportunity for greater engagement with bus operators in London on the topic of fuel cell buses and thus helped to raise awareness of the latest developments in the sector. Outputs from this work are due to be published during spring / summer 2018.

While significant progress has been made in the UK cluster towards procuring many tens of fuel cell buses with a common specification, as of early 2018 orders for these vehicles have not been placed and further work lies ahead. The short-term actions for the partners involved in the UK cluster include:

- Proceed with delivery of the new fuel cell bus fleets and refuelling infrastructure in the JIVE / JIVE 2 cities. The immediate next steps are to place orders for the vehicles and to proceed with procurement exercises for the refuelling infrastructure that will be required (for those cities without existing plans in place).
- Continue to share information and best practice with the “observer cities” elsewhere in the UK, and contribute to dissemination efforts targeting wider audiences both nationally and internationally.
- Continue planning larger scale deployment of fuel cell buses in the post-2020 period. A study to help inform TfL’s strategy for zero emission buses beyond 2020 is already underway and is expected to provide a robust evidence base that will ensure fuel cell buses continue to play a role in meeting the Mayor’s ambitious policy targets. Further work to plan the expansion of fuel cell bus fleets in all the cities with aspirations in this area will be required over the coming months and years.

4 Funding and financing fuel cell bus deployment

4.1 Introduction

A typical budget for a fuel cell bus deployment initiative will include as a minimum capital costs for the vehicles, workshop / depot upgrade costs, vehicle maintenance costs, and fuel costs. There are various ways in which hydrogen refuelling infrastructure costs can be covered, such as via direct purchase of the equipment (potentially with a service and maintenance contract), through to per-kilogram payment for fuel where the price covers all costs associated with generating, distributing, and dispensing hydrogen.[40]

While technology costs are relatively high (i.e. compared to incumbent vehicles), fuel cell bus projects typically rely on securing funding from multiple public sector sources (international, national, regional, local). Any project developer must consider not only the overall funding level needed to deliver a project (i.e. sufficient funds available to meet the expected costs over the course of the project), but also the financing strategy – i.e. at what point costs will be incurred and therefore when funding is required.

As the sector moves on to a more commercial footing, these challenges of acquiring and merging different sources of public finance will evolve. The focus will shift to mechanisms to reduce the ownership cost of the bus relative to incumbents to allow private sector decision makers to choose the fuel cell drivetrain and to obtaining finance to allow capital costs to be spread over a long enough period and on a comparable basis to other technologies.

This section focuses on the two stages of project development. The first sections address the challenges faced by project developers today. In the final section, we address the challenges for moving to a more commercial basis beyond 2020 and make suggestions for how these might be overcome.

4.2 Public sector led funding and financing

4.2.1 Project structure

The majority of the fuel cell bus projects planned under the JIVE programme are public sector led; i.e. in most cases city councils / public transport authorities or operators are leading the projects and will own the vehicles. An example structure for this type of project is shown below.

[40] Per-kilogram payment arrangements are often structured as take-or-pay contracts, where customers commit to using certain quantities of hydrogen within defined periods (and paying even if demand falls below the anticipated levels). These types of arrangements give hydrogen suppliers sufficient certainty over future revenues to allow them to invest in the required infrastructure. The ability of HRS providers to finance infrastructure investments depends on these types of contacts and other factors (such as the characteristics of the company itself (e.g. the large gas companies tend to have more access to finance than SMEs in this area).

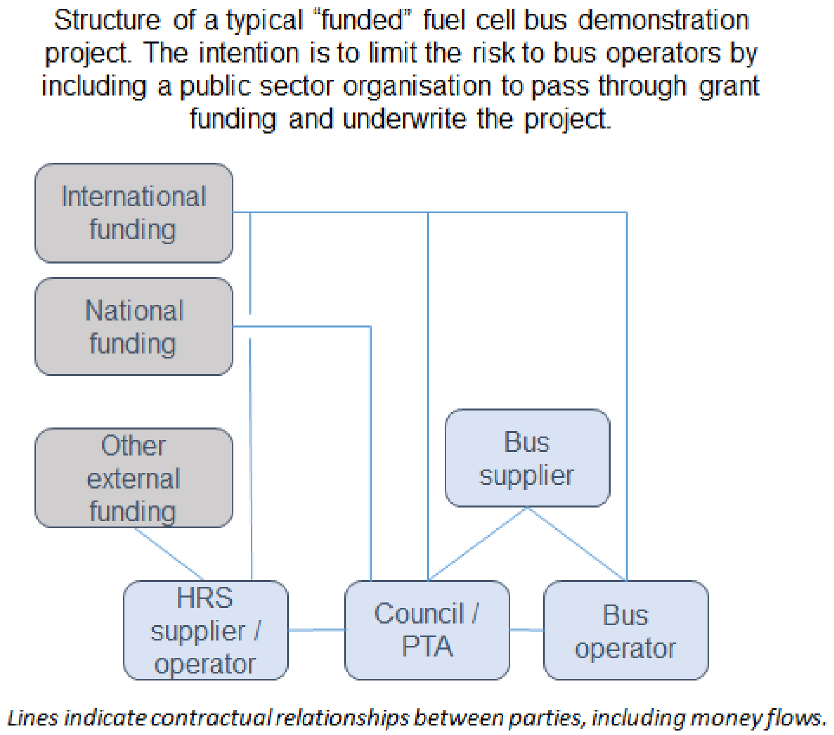


Figure 28: Example structure of a typical fuel cell bus project reliant on subsides from multiple sources – i.e. pre-commercial technology demonstration / validation

Typical arrangements for a fuel cell bus demonstration project as outlined above may be:

- The Council / public transport authority contract directly with the bus supplier for the supply of buses – i.e. vehicle ownership remains with the public sector organisation. Note that this contrasts with the situation in most countries where conventional buses are typically purchased directly by the bus operators. The only countries where vehicles are purchased by the operators are those where the operator is 100% publicly owned.
- The buses are then in some way leased to the operators for a rate dictated by the cost of leasing conventional diesel buses + diesel fuel + diesel bus maintenance allowance (i.e. the financial exposure of the operators is capped to the cost of running equivalent conventional vehicles). The lease period has historically been set by the duration of the funded projects.
- The operators are responsible for maintaining conventional elements of the vehicles, with specialist maintenance (e.g. of the hydrogen and fuel cell systems) being carried out by the equipment suppliers. In some cases it has been possible to transfer these specialist tasks to local operators, but in general the operators take a low-risk approach of looking to contract drivetrain maintenance.
- The HRS may be owned and operated by the HRS supplier, who leases the land on which it is sited from the land owner. A contract for fuel supply is then put in place, either with the Council / PTA or directly with the bus operator. In other cases the entire station is procured by the Council / PTA and operated using a maintenance contract with the original equipment providers.

Note that in this type of model, the Council / PTA uses a combination of international funding, subsidies from national sources, contributions from the bus operator, and its own funds to cover the costs of the project. Furthermore, the Council / PTA typically takes on responsibility for underwriting the project – i.e. carrying risks related to uncertainty over costs, technology performance, etc. Some of these risks are passed on to bus / refuelling infrastructure technology suppliers but in general it is necessary to limit the exposure faced by the bus operators and hence these risks are borne by the public sector.

4.2.2 Funding strategy

Overview

In this section, we illustrate the typical approach to funding using a generic example for a project involving 20 new fuel cell buses with the economics which are available today. The key assumptions underlying this simplified analysis are tabulated below. Note that this is not intended to be a comprehensive list of all costs associated with this type of project.

Table 3: Cost and funding assumptions for an example fuel cell bus demonstration project (20 buses)

Assumption	Unit	Value	Notes
FC bus capex (per bus)	Euro	625,000	Target in the FCH JU's 2017 AWP (standard 12m bus) – expected pricing level for buses ordered in 2018/19. Note that lower cost targets have been published by some industry representatives – e.g. see the Ballard breakdown of a 500k euro FC bus below.
Equivalent diesel bus capex (per bus)	Euro	200,000	Assumed contribution from operator is pro-rated using this figure, an assumed (financial) lifetime of 12 years, and linear depreciation.
FC bus fuel consumption	kgH_2/km	0.065	Relatively low compared to figures seen in past demonstrations, but achievable for single deck buses based on latest indications from suppliers.
Equivalent diesel bus fuel consumption	Litres/100km	37	Typical diesel bus fuel consumption.
Average annual mileage per bus	km/yr	65,000	Typical value.
Hydrogen price (ex. VAT)	Euro/kg	5	Price to PTA / operator. This is an all-in price that needs to cover hydrogen production and all equipment needed to store and dispense the fuel. This value is aggressive (e.g. compared to the JIVE 2 project target of €9/kg) but achievable under the right conditions.
Diesel price (ex. VAT)	Euro/litre	1.2	Represents a hedged price over the period of operation.
FC bus maintenance cost	Euro/km	0.35	Illustrative value, consistent with recently published targets for large fleets of fuel cell buses and including maintenance of the FC module, conventional parts, other powertrain components, and an allowance for stack replacement during the lifetime of

			the bus. This figure is optimistic for a fleet of 20 buses. Further context is provided below.
Equivalent diesel bus maintenance cost	Euro/yr	20,000	Typical value.
Bus depot upgrade cost	Euro	100,000	Covers costs of safety checks, installation of hydrogen sensors and other specialist equipment needed to maintain FC buses in a standard depot. Illustrative figure. Excludes hydrogen refuelling station equipment (assumed to be covered in the hydrogen price – see above).
International funding	Euro/bus	200,000	Illustrative figures that show a shared financial commitment between international, national, and local bodies. The amount of public funding available may well decrease over time (with falling prices of FC buses).
National funding	Euro/bus	100,000	
Local funding	Euro/bus	230,000	

Fuel cell bus capital cost breakdown – illustration for vehicles from 2020

As noted in the table above and in section 3.5.2, certain suppliers of fuel cell buses and their components have published more aggressive cost targets than those assumed in this analysis. For example, in 2016 Ballard published a paper promoting fuel cell buses for the UK market, which included the following breakdown of a target capital cost of €500k per bus for vehicles ordered in 2020.

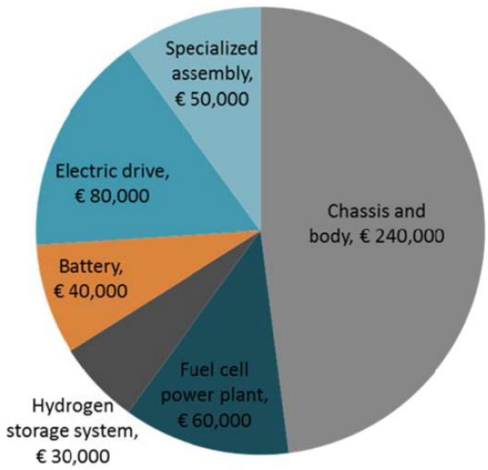


Figure 29: Fuel cell electric bus component cost estimate with a 60kW fuel cell power module (2020) – source Ballard[41]

Fuel bus maintenance costs

The main elements of fuel cell bus maintenance include costs associated with maintaining the fuel cell and hydrogen system, other powertrain components, and conventional elements of the bus. When considering operation over the full life of the base bus (typically 10–15

[41] *Fuel cell electric buses: an attractive value proposition for zero-emission buses in the United Kingdom*, Ballard (November 2016).

years), it is necessary to consider the replacement / refurbishment costs of high-value elements of the drivetrain (in particular the fuel cell system). According to the proponents of the commercial fuel cell bus for Scandinavia:

"*As the technology proliferates and the supply chain matures, a fuel cell drivetrain will generate operational savings in comparison to a diesel engine. For an electric drive motor on a bus, there is no expected electric motor repair or maintenance needed other than a potential bearing replacement during the typical useful life of a bus. Overall, fuel cell buses require less regular maintenance due to its solid state design and minimal moving parts. With volume, maintenance costs (including fuel cell stack replacement) will be at or below that of a diesel bus. Current forecasts show that the maintenance cost for fuel cell buses is close to aligning with diesel buses at €0.35 per kilometre at a volume of 100 buses per year.*"[42]

It is important to realise that the €0.35 per kilometre maintenance cost referred to here is an average over the operational life of the vehicle. In practice, maintenance needs vary through time (as they do with conventional diesel buses), with a low maintenance requirement for the first year or two of operation (when most parts are also under warranty), and the potential for relatively high one-off parts replacement costs as the vehicles reach mid-life. The maintenance costs that early adopters of fuel cell buses face will also depend on the risk appetite of the operators and the extent to which they are willing to train their own technicians to carry out basic maintenance tasks versus desire to opt for all-inclusive maintenance packages where the suppliers provide experts to carry out the required work.

Depot upgrade costs

In this analysis, a relatively optimistic figure of €100k for bus depot upgrades is included. An illustration of how this cost could be divided is given below.

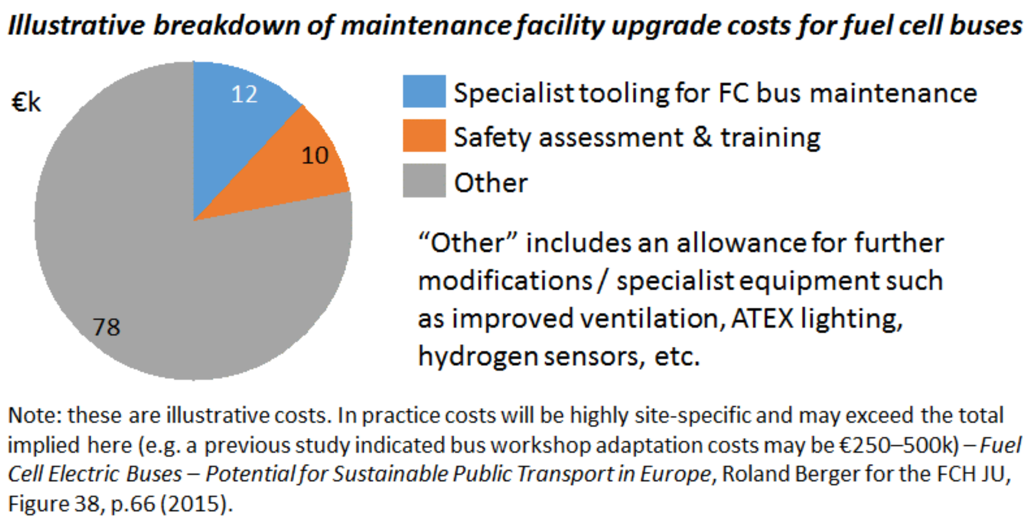


Figure 30: Illustrative breakdown of fuel cell bus maintenance facility upgrade costs

Note that this cost allowance is towards the lower end of the budget that should be included for preparing existing maintenance facilities for the introduction of fuel cell buses. The budget required in practice will depend on the specific circumstances of the depot(s) in question and an early task in preparing for fuel cell bus deployment is to engage a suitably

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[42] *Fuel Cell Buses: an attractive value proposition for zero-emission buses in Scandinavia, 2nd Edition*, Ballard, NEL, Hydrogen Valley (April 2018).

qualified expert to undertake a safety assessment and advise on mitigation measures required. As indicated above, such an assessment should be possible with a site assessment, review of existing facilities and practices, etc. that should be deliverable for around €10k or below. Any city / operator planning a fuel cell bus project would be advised to include an allowance of around €100k – €300k for adapting existing depots to house fuel cell buses, and to note that the budget could be multiple times this if the plans involve building a new depot from scratch.

Overall cost and funding breakdown

This illustrative example is based on a seven year project, including five years of full operation of the buses in service. With the high-level assumptions summarised above, the project costs are matched by the combined funding as shown below.

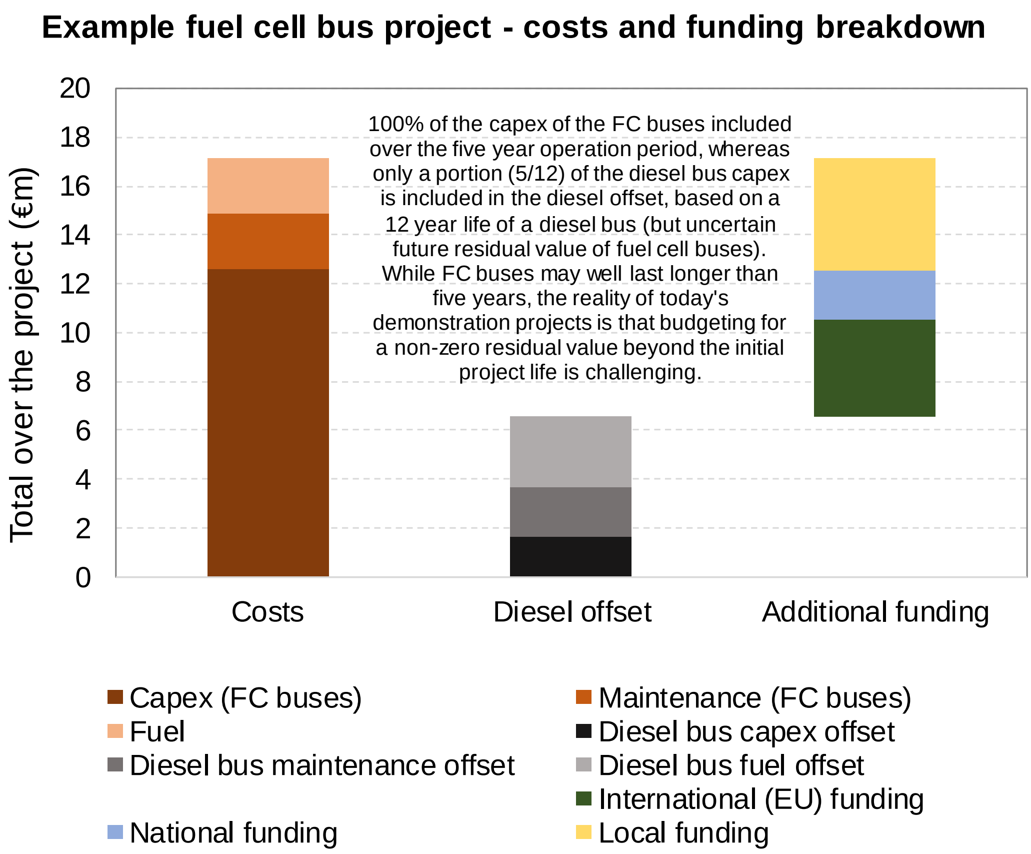


Figure 31: Illustrative costs and funding (including contributions from bus operator capped at the cost of operating equivalent diesel buses) for a typical fuel cell bus project in operation for 5 years

This analysis shows that over the course of the project, the total funding available covers the anticipated costs. It is also important to consider when the costs are likely to be incurred and when funding will be available (i.e. the project cash flow), as this reveals the scale of any financing need. This is the topic of the following sub-section.

4.2.3 Cash flows and financing

By making a series of assumptions, we can explore the potential cash flows over time for the typical project outlined above. For the purposes of this analysis, we assume:

- Fuel cell bus capital costs (and depot upgrade costs) are incurred up-front, i.e. within the first two years of the project (e.g. partially upon order of the buses in year 1 and partially upon delivery of the vehicles in year 2).
- The remaining major costs (for bus maintenance and fuel) are constant for each year of operation.
- International funding is paid in instalments: pre-financing in year 1, followed by a series of payments in years 2 and 3. A small portion of the total grant (5%) is withheld until the end of the project (year 7).
- National funding is paid in full in two equal instalments in the first two years of the project (mirroring the capital spend profile on the buses), while local funding is spread evenly over the course of the project.

The resulting cash flows from these assumptions are shown below.

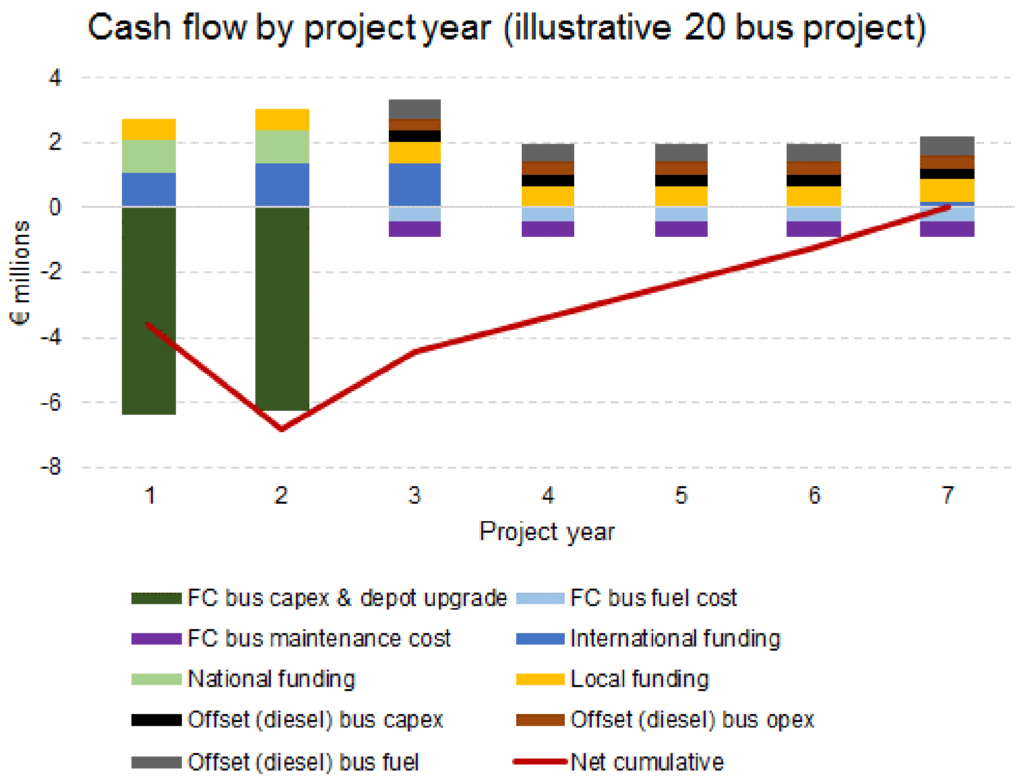


Figure 32: Example cash flows for a fuel cell bus project in the pre-commercial phase

This analysis reveals that there is a significant financing need, with a negative cash flow of c.€6.9m in year 2 of the project.[43] The approach in most of the projects of this type to date has been to rely on financing from the public sector organisation(s) involved (the PTA or council). Generally, the budgets which these local authorities use are such that the cashflow impact of front loaded costs have been manageable within the annual accounting cycle, as the costs of the project are relatively small. However, as the projects grow in size, we are seeing an increasing number of authorities (particularly in jurisdictions with tight public sector budgets such as the UK) struggling to cope with this typical front-loaded spend profile.

[43] Depending on the details of arrangements (contractual terms) for the hydrogen refuelling infrastructure, the financing need could be significantly higher – e.g. if capital for purchase of infrastructure is required. In this example, these costs are assumed to be spread across the project lifetime in the form of an all-inclusive hydrogen price.

An alternative approach would be to arrange different payment terms for the buses – i.e. rather than paying the full capital costs up-front (by the time of bus delivery), a financed offer (or a lease) could be sought. To date we have not identified either a bus manufacturer or leasing provider able to facilitate a financing offer of this kind.

Finally, grant bodies could also help to support cities in managing these issues by providing increased quantities of funding as pre-financing or in the year when the capital costs are incurred rather than only funding the depreciation of the assets.

4.2.4 Conclusions

The type of funding and financing arrangements outlined above have proven suitable for pre-commercial demonstration projects involving the most innovative PTAs / councils. One of the advantages is that the costs (and hence risks) associated with deploying and operating new technology are shared between multiple funders. This also means that each funder's contribution is leveraged against funds from other parties.

By combining public sources of funding, private sector operators can be insulated from most of the financial risks, leading to a more acceptable overall offer to the private sector operator who limit their financial exposure to the levels they are comfortable with for diesel bus projects whilst accepting the risks and hassle associated with learning to operate unfamiliar technology.

However, projects funded by multiple organisations can be complex, and time-consuming to establish and run. Larger scale roll-out of fuel cell buses will rely on further cost reductions such that it is not necessary to combine multiple funding / financing sources. Clearly, some form of on-going subsidy for zero emission buses will be advantageous in terms of making a business case for adopting these vehicles, but with more competitively priced vehicles the focus will shift from securing large grants to securing financing for the vehicles (and infrastructure) over their lifetimes.

In addition, as we progress to a more commercial deployment model, the financial risks will need to transition away from local authorities and PTAs and back towards the operators and their technology suppliers. When this happens, the financing issue will become more focussed on the approach to risk sharing between the bus / technology suppliers, bus owners, and any third party finance providers. This is covered in the next section on the post 2020 financing issues.

4.3 Financing fuel cell bus deployment beyond the subsidised phase (post 2020)

4.3.1 Overview

The previous section summarises the typical approach to funding and financing fuel cell bus projects which has been adopted to date. Such projects are characterised by relatively high costs (of buses and infrastructure), short durations (relative to the typical life of a conventional bus), and large public subsidies. There are several non-technical barriers to larger scale roll-out of fuel cell buses on a sustainable, commercial basis, including:

- Bus capital costs
- Bus maintenance costs
- Cost of hydrogen
- Asset lifetime and residual values

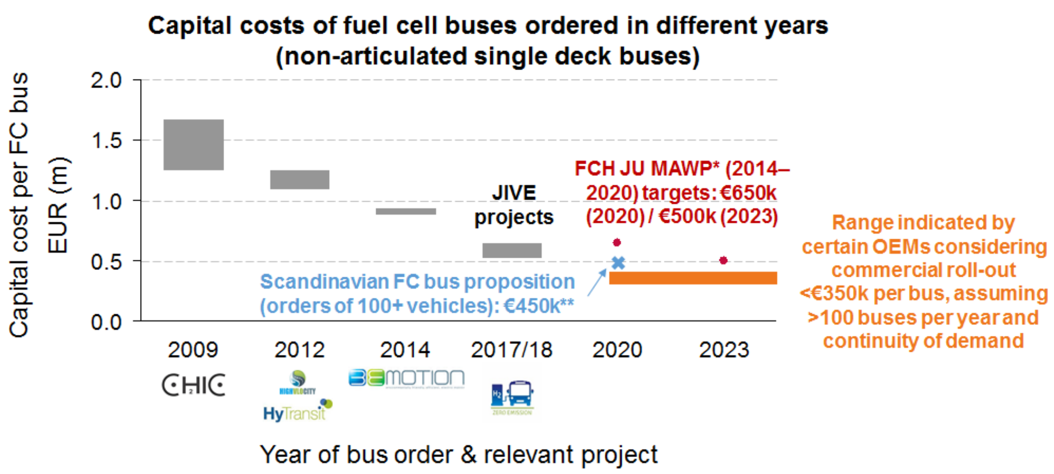
- Cost of finance

This section explores each of these issues in turn, considering the current situation and changes required for fuel cell buses to become a more attractive commercial solution

4.3.2 Fuel cell bus capital costs

Challenge

While the technical performance of fuel cell buses has been validated in several demonstration projects[44], the capital costs (and hence prices) of these vehicles remain well above equivalent diesel buses that they are designed to replace. The graph below indicates the progression of typical capital costs of fuel cell buses in Europe over the past decade.



* ***FCH JU MAWP*** is the Fuel Cells and Hydrogen Joint Undertaking's Multi-Annual Work Plan, the document that sets out the work plan and strategic targets for the second phase of the FCH JU's programme of research and innovation.

** See http://hydrogenvalley.dk/white-paper/.

Figure 33: Progression of typical fuel cell bus costs in Europe – historical figures and projections to the early 2020s

The costs of fuel cell buses deployed through past demonstration projects have been relatively high due to the niche nature of these products: i.e. a combination of non-recurring engineering costs having to be covered over a small number of vehicles, high component costs, and high assembly costs contribute to a significant premium relative to traditional buses. While significant progress in reducing fuel cell bus costs has been made in recent years (e.g. prices below €650k per bus for vehicles ordered in the JIVE project), further reductions will be needed for this technology to compete with other zero emission options and / or ultimately with diesel buses.

Potential solution

Discussions with several bus OEMs during this project have indicated that under the right conditions significant further reductions in the costs of producing fuel cell buses are achievable. These conditions include:

- **Scale of demand** – the costs / prices of buses supported by the major European demonstration projects are based on small order numbers per OEM (a few / few tens of units). A scale of low hundreds of buses produced per OEM is expected to

[44] Such as CHIC (http://chic-project.eu/) and High V.Lo-City (http://highvlocity.eu/).

provide meaningful cost savings and bring capital costs into the range of other zero emission options.

- **Continuity of future demand** – certainty over future demands for fuel cell buses is perhaps as important as the total scale of demand. This is due to the fact that OEMs can make substantial cost savings by setting up and filling a dedicated production line for fuel cell buses and by passing on this certainty to their suppliers who can then make similar investments.

Initiatives are now underway that are seeking to address both of these points in a number of markets. The Fuel Cell Bus initiative in Scandinavia is an example of the type of initiative required to further reduce the capital costs of the buses. These approaches build on the central principle of this project of aggregating demands for zero emission buses, while seeking to put in place mechanisms that provide sufficient certainty over future demands for fuel cell buses. Further detail on this topic is provided in the planning beyond the subsidised phase section below (section 5.2).

4.3.3 Fuel cell bus maintenance costs

Challenge

With a tendency to focus on capital costs, the maintenance costs of fuel cell buses are an often neglected item. If the cost of maintenance is higher than for a diesel bus, this is a cost which must be borne by the public authority wishing to move to fuel cell buses. There are two costs which need to be considered here:

- The day to day cost of maintenance – which can be higher than for conventional buses due to the need for specialist personnel to carry out maintenance tasks, higher replacement rates for certain components and the cost of specific components (e.g. more expensive air filters).
- The cost of overhaul – the expected life of a fuel stack is now well over 20,000 hours. This is enough to ensure perhaps only one replacement over the life of a bus, but it is unlikely that an overhaul of the drivetrain can be avoided. This leads to considerable costs for the replacement of fuel cells and batteries within the drivetrain and tank inspections are often needed. These costs are typically higher than for a conventional diesel bus and need to be factored in when planning the whole life financing of a new project.

The additional cost of maintenance is a cost which can adversely affect the financial viability of a fuel cell bus scheme and needs to be addressed in any move towards commercial viability in the 2020s. To illustrate the point, today's projected drivetrain replacement costs can easily exceed €100,000, significantly higher than the ~€20k paid for an engine overhaul at mid-life for a bus. This additional €80k of costs must be found within the overall financial structure for the bus operations.

Potential solution

Scale – as for the capital costs, economies of scale will help to bring down many of the day to day maintenance costs. This scale applies at two levels:

- If an OEM is deploying many fuel cell buses, the cost of procuring replacement components and then sending staff to fix issues will be reduced.
- If a large fleet of buses is deployed at a single location, the cost of employing specialist personnel is spread over a much larger number of buses and hence the day to day cost of maintenance per vehicle is reduced.

It is recommended that as part of future projects aiming to provide scale to bus manufacturers that maintenance costs should be a significant negotiating item, with a view to driving down contract maintenance costs and cost of spares as an integral part of any project. For example, in the Scandinavian initiative, a target maintenance cost of €0.30/km is declared as part of the pledge if a 100 bus order can be secured.

Technology improvement – the other factor which will help on the maintenance costs is improvements in the technology. In particular the stack technology itself will benefit from improvements to lengthen life and reduce the cost of replacements through innovations currently being introduced at the stack level. Stack manufacturers are also developing techniques to strip down as opposed to completely replace fuel cell stacks as a way or minimising the costs. For the technology to be fully competitive, technology developers should ideally target a lifetime in excess of 35,000 hours (to ensure a seven year replacement cycle) and a replacement cost equivalent to a diesel engine. All costs which are higher than this level need to be compensated for in the financial structure e.g. through lower hydrogen prices or by the public transport provider accepting a higher cost of operating the buses.

4.3.4 Cost of hydrogen

Challenge

For parity with a diesel vehicle, a cost of hydrogen of €5–6/kg is required. For example if we assume fuel cell bus hydrogen consumption of 7.5kg/100km, an equivalent diesel bus at 35l/100km and a diesel price of €1.1/litre, the cost of fuel for parity is €5.1/kg.

Unfortunately, today it is very challenging to achieve prices for hydrogen at this low level. This means the additional hydrogen costs must be financed as part of the overall hydrogen bus project.

Solutions

Scale – the main reason for today's high hydrogen prices is a lack of scale at the bus depot. Without economies of scale, the high capital costs associated with hydrogen compressors, storage tanks and dispensers dominate the cost of hydrogen. These issues are explored in detail in the NewBusFuel report and not repeated here.[45] In general, evidence from the clusters backs up the findings in that report and suggests fleet sizes of over 50 buses are required in order to hit the price targets above. This leads to the recommendation that future projects should be based on depots with a plan to rapidly expand their hydrogen fleets to larger scale deployments of the order of 50 buses or more.

Low cost energy – the other factor which affects hydrogen price is accessing a low cost source of energy. Whether hydrogen is derived from electricity or hydrocarbons an input fuel cost of below €50/MWh is likely required to hit the targets above. This means that achieving a low hydrogen price in any location will require a search for the lowest cost sources of energy and will require considerable local optimisation. It is recommended that future sites look to optimise their hydrogen sourcing according to the lowest cost available sources of energy in their area which also meet the environmental requirements for their projects.

Longevity of contract – the longer the high capital cost items can be depreciated over at the refuelling station, the smaller the impact of these costs on the per-kilogram price of hydrogen. The difference in cost of hydrogen for a five year versus 15 year expected lifetime

[45] See www.newbusfuel.eu.

can be as much as €2/kg. This suggests that where possible authorities moving to hydrogen should look to enter into contracts for equipment supply which are as long as possible and where long contracts cannot be guaranteed due to standard contracting procedures, these procedures should be challenged. Where these longer contracts cannot be offered by the local actors, there may be a role for state intervention for example from the EIB or national lenders using subsidised debt to offer longer term financing and hence reduce the cost of hydrogen.

Reduced cost equipment – a number of fuelling station manufacturers are developing lower cost refuelling station equipment specifically designed for bus depots (see for example, Nel, Linde, Air Liquide). These tend to work by minimising the amount of equipment required on site by sharing components (e.g. cooling) or by moving to a model where most of the production is carried out off site. These technology improvements can be expected to be incorporated into products and reduce the cost of stations over the next five years.

4.3.5 Asset lifetime and residual values

Challenge

A standard diesel (or diesel hybrid) bus may have a useful operational life of 12–15+ years and owners of these vehicles typically depreciate them over this period. In contrast, fuel cell buses are currently typically deployed as part of funded projects with a shorter duration (e.g. five years of operation). While the JIVE projects are seeking to demonstrate fuel cell buses over longer periods, the empirical data from these trials is not yet available. Therefore, owners of fuel cell buses usually must depreciate the vehicles over a relatively short period.

The impact of this on the effective ownership cost of the bus (considering capital cost only) is illustrated in the graph below, which shows the magnitude of the effect if a fuel cell bus is depreciated over five years compared to a diesel bus over 14 years. The graph is based on relatively low fuel cell bus costs (€400k) and shows that even after all the effort has been made to reduce the capital cost of the bus, the fact that lease companies and operators may only depreciate the bus over a limited period could push the fuel cell bus back into being uneconomic.

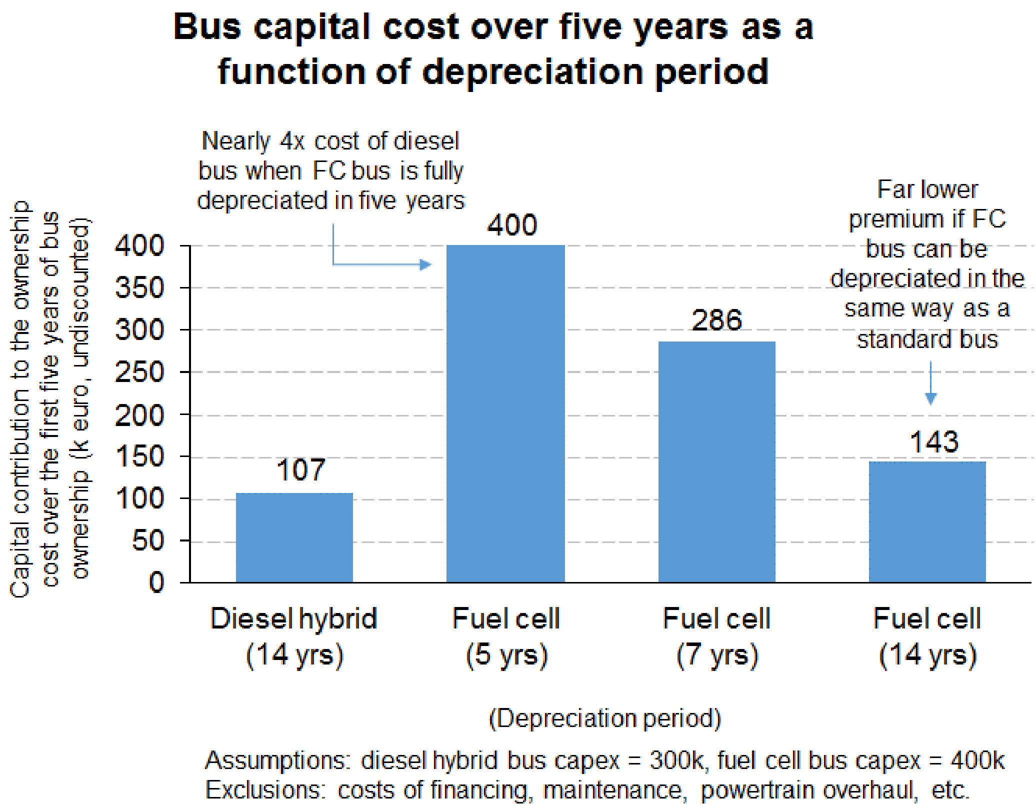


Figure 34: Illustration of effect of depreciation period on cost of a bus over the first five years of life – capex only (based on indicative future FC bus capex that may be available following deployments in the JIVE project)

It is worth noting that this depreciation / residual value issue also affects battery electric buses. This results from the high rate of progress in terms of technology development and cost reduction, uncertainty over refurbishment / on-going maintenance costs (particularly beyond the initial warranty / contracted maintenance period), and no established second hand market.

Leasing (rather than outright purchase) is an attractive option for some bus operators, provided that the lease rate is competitive. However, any leasing company will need to build in a residual value assumption for the vehicles at the end of the lease period and without evidence of the potential second hand value of fuel cell buses, the lease option simply shifts the *depreciation issue* from one party (the operator) to another (leasing company), who then charge a higher lease rate back to the operator as they don't have certainty over the residual value.

Potential solution

Use of subsidised debt – the benefit of being able to depreciate a fuel cell bus over a period comparable to a conventional vehicle is clear. Mechanisms to enable this are now under development as part of the on-going work on planning fuel cell bus deployments beyond 2020. For example, discussions have taken place with the EiB over the potential to use subsidised debt to allow for longer life leases than would be available from a conventional leasing provider. These discussions suggest there is a recognition of this issue for all zero emission options and a willingness to consider this type of debt provision for fuel cell buses.

Experience and data collection – through time this issue should be resolved through improved awareness of the fuel cell bus technology amongst lease providers and operators due to increased operational experience. It is very important that the early demonstration projects collect data on the longevity of the buses and hence provide an evidence base to the debt providers of the technology reliability for longer term leases.

Longer term commitments from bus operators and PTAs – the PTAs can play a significant role in reducing the cost of leases by issuing guarantees that zero emission buses will be found a use beyond standard contractual terms agreed with their operators (ideally for the whole of their useful life). By issuing statements of this type, the PTAs give confidence to the lease companies that there will be a second hand market for their product and hence improve the residual values included in the leases.

Manufacturer support – lease providers will also take note of the manufacturer support for the product. If manufacturers can have discussions with leasing providers about the longevity of the buses, the way in which the manufacturers can stand behind the product over its full operational life and potentially even a pledge to retrofit to other drivetrain technologies if the fuel cell drivetrain is no longer wanted, this will all help improve the lease company residual value calculations.

4.3.6 Cost of finance

Challenge

Based on numerous discussions with bus operators, it appears likely that access to low cost finance (*soft debt*) will be beneficial in rolling out larger fleets of fuel cell buses in the post-2020 near commercial period. Depending on interest rates, financing costs can be high relative to the capital costs over the lifetime of a vehicle.

Although capital and financing costs of vehicles are only a portion of the total costs of owning and operating buses (e.g. driver salaries are typically the single largest component of the total cost of ownership for a bus), access to low cost finance is a useful enabler, especially when customers are faced with high up-front capital costs.[46] Experience from the JIVE project suggests that finding ways to spread the capital cost of fuel cell buses over several years will be important in reducing the barriers to further deployment, particularly when fleets get larger and hence cost more, causing more of an issue for operator balance sheets.

Potential solution: low cost finance from the European Investment Bank

The PTO of Riga (Rigas Satiksme) sought opportunities to use financial instruments to support the construction of a hydrogen refuelling, production and storage facility and attracted a European Investment Bank (EIB) loan. At the application stage, it was agreed that the loan could be used for zero emission vehicle implementation throughout Riga (part of the "Juncker Plan"[47]). The loan covers the construction of hydrogen refuelling, production and storage facility, as well as 10 hydrogen fuel cell buses and 10 trolleybuses with hydrogen fuel cell range extenders. The EIB loan also covers the purchase of 20 new low-floor tram

[46] Some organisations have access to very low-cost finance as part of their existing business activities. However, this is not the case universally and making soft debt for these types of vehicles widely available would help to support development of this market.
[47] Investment Plan for Europe: the Juncker Plan. See: https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan_en

units to operate in Riga, as well as the modernisation of tramway infrastructure. The EIB loan is divided into three tranches, covering:

1. The hydrogen refuelling, production and storage facility together with 10 trolleybuses with hydrogen fuel cell range extenders.
2. Ten fuel cell buses planned as part of the JIVE project. Note that under this tranche of financing there is the opportunity to increase the number of fuel cell buses beyond the ten originally envisaged.
3. The 20 trams and their infrastructure.

Taking into account that the EIB loan as part of the “Juncker Plan” does not request additional warranties and the bank interest rate comparison with private sector loans, it will decrease the overall cost of ownership for all vehicles covered by the loan, which can in turn be used to support the choice of zero emission vehicles. Rigas Satiksme together with Latvian Academy of Sciences is spreading the experience of how to attract the EIB loans to other Northern Europe cluster partner cities.

The European Investment Bank is seeking to support the accelerated deployment of cleaner transport technology via the *Cleaner Transport Facility*. Together, the EIB and the EC offer a range of tools, products (loans / guarantees / equity investments), and advisory services (financial advice, technical assistance) that are relevant for planning large-scale deployment of zero emission buses. The optimal solution in terms of financial instruments and commercial structures is likely to depend on various project-specific factors such as scale of vehicle roll-out, partners involved and attitudes to risk, and timescales for deployment and operation of the hardware.

5 Outlook for Europe's fuel cell bus sector

5.1 Potential demand for fuel cell buses

By aggregating the figures of demand for fuel cell buses by cluster presented in section 3, the overall potential demand at a European level is revealed. We have estimated the potential demand by classifying fuel cell buses into a series of categories:

- **In service** – buses that are currently operating.
- **Funded** – new buses planned as part of projects that have received funding and are in a delivery phase.
- **Very likely** – new buses planned as part of projects under development, e.g. for which funding applications have been submitted but that are not yet fully confirmed.
- **Possible** – represents buses for which there is potential demand but for which no funding has been identified.

Using this classification, we can assess the likelihood of reaching the aspiration to establish a demand for c.1,000 fuel cell buses across Europe (see section 2.1).

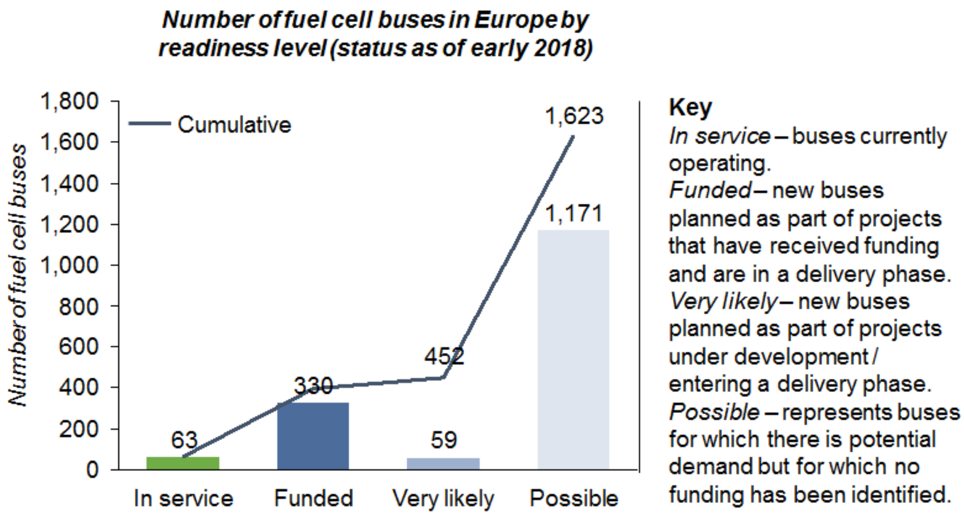


Figure 35: Number of fuel cell buses in service, planned for deployment ("Funded" / "Very likely", and potentially demanded ("Possible") across Europe

While there is a relatively high level of confidence in delivering buses up to and including the "Very likely" figure (i.e. up to c.450 vehicles), realising the potential represented by the "Possible" category will require several further developments:

- Successful delivery of the next wave of buses via the JIVE / JIVE 2 projects, leading to additional evidence of the technical performance of the vehicles and associated infrastructure. This is a crucial next step as the appetite for further large-scale uptake of fuel cell buses is likely to remain limited until there is widespread acceptance of a range of proven technologies being available.
- Further cost reductions (capital costs and maintenance costs) for fuel cell buses to a level where the need for public subsidy is significantly reduced / eliminated in some of the most environmentally sensitive areas.

- Continued development of the supply side – e.g. an expanded range of fuel cell bus models available, improvements in the supply chains, and greater capacity of suppliers to support increasingly large fleets in service.
- Progress in developing and delivering cost effective hydrogen supplies for large fleets of buses, i.e. many tens to low hundreds of vehicles per location, building on the conclusions of the NewBusFuel study.

5.2 Planning beyond the subsidised phase

The fuel cell bus demand figures summarised above indicate strong demand for these types of zero emission vehicles from cities across Europe. However, the current wave of fuel cell bus deployment is supported by large public sector led subsidies. This model is unsustainable in the medium term, as there is not sufficient funding available to support an increasing roll-out of buses at these levels. This means that a new approach to continued roll-out of these vehicles is needed for the post-2020 period.

Within this project, Element Energy led a task dedicated to considering how fuel cell buses could be introduced on a commercial basis following the subsidised demonstration projects. This involved holding dedicated discussions with selected bus operators to assess the needs and constraints of the vehicle end users, and then working with industry partners (bus OEMs and hydrogen suppliers) to understand the conditions under which lower cost fuel cell bus solutions could be made available. The result of this exercise was a *White Paper* on commercialisation of fuel cell buses[48], which Element Energy wrote in summer / autumn 2017 and key features of which are summarised below (see also section 3.6.4).

OEMs willing to engage with lower priced fuel cell bus activity

The White Paper is mainly based on productive discussions with a limited number of European OEMs who have recognised the potential to push for fuel cell buses and acknowledge the potential to reduce costs linked to large increases in volume. These OEMs tend to be the slightly smaller 1,000–2,000 bus/year manufacturers who have recognised the potential for zero emission buses to be transformative for their businesses as they look to grow both in their home markets and expanding into future export markets. They also without exception are dedicated bus manufacturers and do not have wider ties to larger automotive groups and associated trucking divisions. The other main driver for these manufacturers to engage is the level of regulatory push for zero emission vehicles in their home markets. For example we see significant engagement from OEMs in the UK, where London has made a commitment to move to exclusively zero emission buses and to mandate new bus purchases (single deck) must be zero emission from 2020 (see section 3.6).

Discussions with these OEMs have indicated that they need continuity of demand in order to reduce prices. A consensus suggests that with a regular demand of around three buses per week (per manufacturer) it becomes possible to introduce a new dedicated fuel cell bus production line and to obtain significant price advantages from suppliers by offering regular long-term supply contracts. Manufacturers have suggested that achieving these volume targets could lead to prices for a 12m single deck bus in the range €330k–€450k.

[48] *Commercialisation of hydrogen fuel cell buses*, Element Energy (2017). Available from www.element-energy.co.uk/publications/.

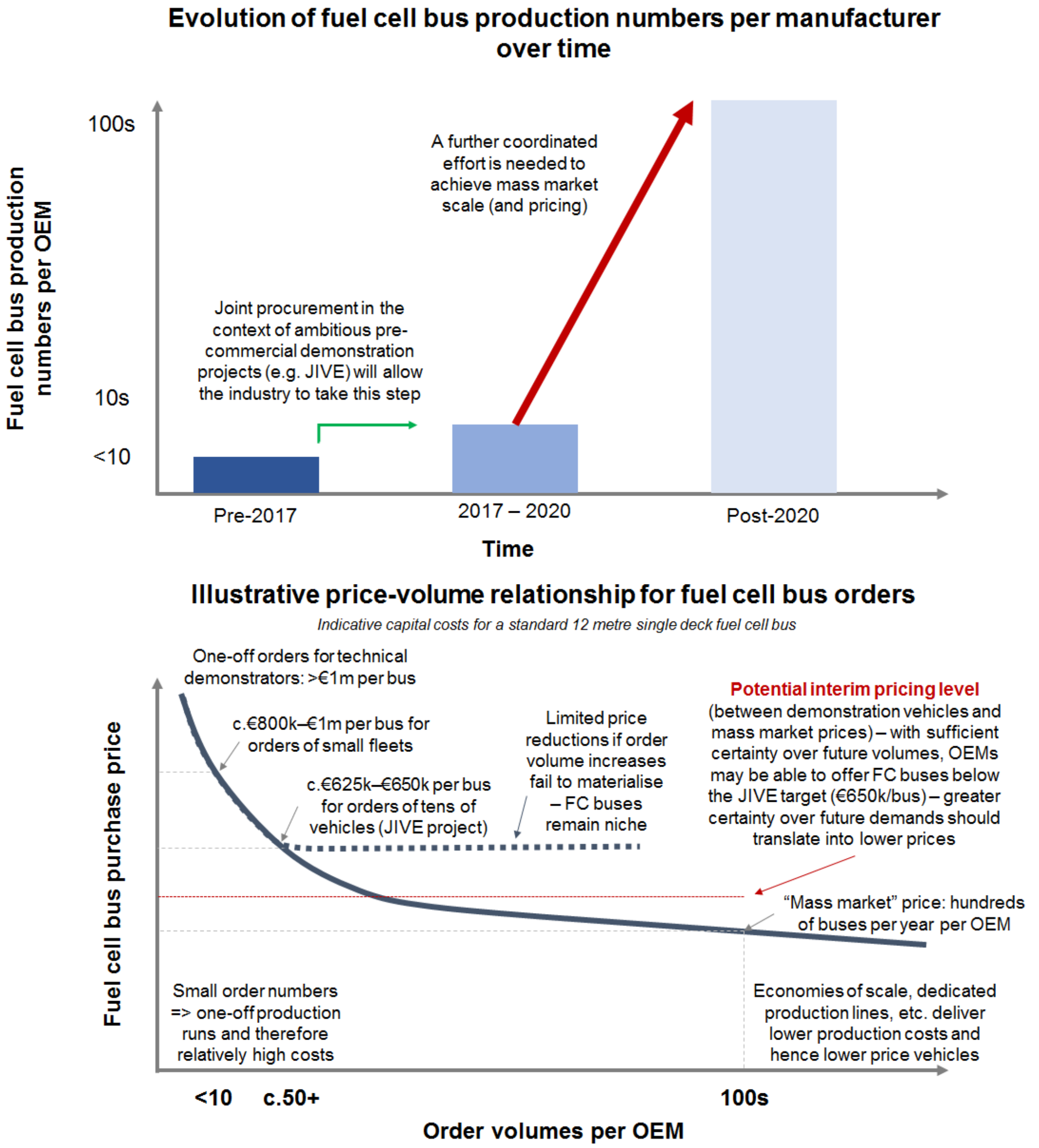


Figure 36: Illustration of scale-up in production numbers and price-volume relationship for fuel cell buses (note that these graphs are purely illustrative and not based on empirical data)

Using these figures, it is possible to understand the effect of vehicle capital costs on the overall ownership cost of a fuel cell bus. This is illustrated in the results presented in the UK cluster section above (e.g. see Figure 26, section 3.6.4), which show the ownership cost of a fuel cell bus compared with a range of alternative drivetrains. The analysis suggests that at these higher volume prices the fuel cell bus can compete with the battery electric bus and is within a plausible percentage of the ownership cost of diesel and diesel hybrid buses.

The plans of a number of cities to ban the diesel and diesel hybrid option through the use of zero emission mandates, will create a significant market within which the fuel cell bus can be competitive. This will be particularly true for routes with long operating cycles and for heavier buses (18m or double deck) where the battery bus will struggle to compete without significant extra buses to meet the needs of the route.

This leads to a first recommendation for moving beyond the subsidised phase. **Recommendation: Push for an increasing number of cities to adopt zero emission**

mandates for city centre buses. This in turn creates a market in which fuel cell buses can compete. It is also a signal to bus OEMs to begin investment in scaling up fuel cell bus manufacture and hence to attract more OEMs to the low cost, high volume opportunity being discussed here.

However, if the only measure taken is to create a market for zero emission buses, it is unlikely that the fuel cell bus will achieve enough scale to become competitive. This is because the battery electric bus is more commercially mature and there is a risk that it will dominate the market, freezing out the fuel cell bus and preventing the mass market volume / cost relationships discussed above. As a result, a series of other measures are being discussed to help drive down prices to affordable levels:

- Ambitious demand-based projects (supplier led) – the JIVE project is attempting to organise a heavily public sector led joint procurement approach to increase demand. It is becoming apparent that the reliance on the public sector to drive demand is helpful in getting the market to start moving, but leads to a number of inefficiencies in delivery which mean that this approach is unlikely to be suitable for a larger scale roll-out. Instead, a more efficient approach would be to encourage the private sector bus suppliers (and other stakeholders e.g. hydrogen suppliers) to come forward with proposals for the way in which demand for their products could be aggregated to lead to lower prices. More specifically, if a manufacturer felt sufficiently confident to begin offering a low bus price subject to achieving a given volume, it becomes possible to start commercial negotiations with operators at prices which do not require large subsidies and large involvement of risk-bearing public sector organisations. This in turn makes the bus buying process less complex and could create a virtuous circle where it is fairly easy to imagine reaching the volume targets articulated by the bus manufacturers.

  This model was described publicly in the Scandinavian hydrogen bus initiative, where an explicit link between the demand for 100 buses and a price target of €450k was made. In our discussions with the leading manufacturers, we have also become aware of a number of other private sector partners pursuing a similar approach.

  The challenge for models of this type is that often the bus suppliers do not have the resources or the hydrogen sector competences required to bring together all the partners required to aggregate and synchronise demand themselves. This suggests there is still a role for some form of coordination of demand by a third party. An example of this comes from France where the CATP procurement agency is now developing a large procurement framework for hydrogen buses which can be called off by any operator in France. An alternative is to continue the cluster work, but encourage cluster coordinators to work much closer with private bus manufacturers and hydrogen suppliers to offer a low cost solution, only available with demand certainty.

- Helping manufacturers manage demand risk (direct intervention in the supply chain) – the key challenge with the approach above is to persuade the manufacturer to take the risk that if they begin offering low prices based on series manufacturing that they will secure orders at the demand levels required to achieve the low prices. Bus manufacturing is a relatively low margin business and this type of forward commitment to low prices on the basis of expected future volume is not something with which bus manufacturers have a great deal of experience, particularly when dealing with novel powertrains which bring their own technology risks. This raises the question of whether there is a way in which this demand risk could be borne by another actor, perhaps the state. A sophisticated approach to public sector subsidy intervention would be to explicitly use public sector funding to help manage the demand risk.

Here, we envisage a scheme whereby manufacturers identify the real financial risk to their business of beginning to offer a hydrogen bus price based on mass market demand and then fail to reach that demand. By quantifying the financial losses which would be incurred, it becomes possible to create some form of guarantee fund, which could be provided by an external agency and would only be payable to cover the manufacturer against losses if they fail to secure the demand. Initial discussions with manufacturers have suggested that the size of this guarantee would be trivial relative to the budgets currently being used to directly subsidise fuel cell bus purchase but could lead to equivalent or even greater savings by enabling the scale up which manufacturers require.

A similar form of guarantee could also be used for component suppliers. Clearly this needs more work but is an interesting concept which will be followed up with manufacturers willing to take advantage of an offer of this type.

- Dedicated hydrogen support – an alternative to the direct interventions around demand described above is to make a less direct attempt to stimulate the hydrogen market. Here, we would envisage that a limited number of route tenders for zero emission routes could be explicitly biased in favour of the fuel cell bus option (subject to meeting a set of price targets). This would be a short-term measure to allow the hydrogen bus to overcome the initial scaling issues and in so doing become a valuable competitor against the battery electric bus. This would need to be justified to cities by demonstrating the medium-term benefits to having both the fuel cell and battery electric buses competing for different zero emission routes and demonstrating that without intervention of this type there is a risk that the fuel cell bus would not develop.

- Hydrogen / zero emission subsidy programmes – in a number of markets it will also be possible to use subsidy programmes for hydrogen vehicles to drive the next phase of hydrogen bus expansion. For example the German zero emission bus incentive scheme (see below) or in the UK there are two national funding pots, one dedicated to low emission buses (up to ~£75k per bus anticipated) and one dedicated to hydrogen vehicles (£14m likely available in 2018, including funding for fuel cell buses and fuelling stations). At a European level the various Connecting Europe Facility funding schemes could also be used to support an ambitious next phase of expansion of the sector, albeit at a funding rate of 20%, which is considerably lower than the percentage funding rates available under the recent FCH JU programmes such as JIVE.

In practice, a combination of the above concepts will be required to move the sector and these willing bus manufacturers to the next level of demand and towards the first commercial sales of fuel cell buses.

In addition, as described above there are several other barriers to resolve once the primary challenge of reducing the bus price is overcome. These are discussed in section 4.3 above and lead to a list of suggested actions for the sector to overcome issues such as the price of hydrogen (mainly through scale at the bus depots), the high cost of maintenance (through scale and technology development) and the low residual values for fuel cell bus technology (through subsidised debt and programmes to increase confidence through the existing demonstrations).

Encouraging additional OEMs to deploy fuel cell buses

While a number of bus OEMs are responding to the opportunities developing in the hydrogen sector, one of the challenges facing Europe's fuel cell bus sector is the lack of response from some vehicle OEMs. It will be hard for the sector to move forwards based on the actions of only a small number of the OEMs in the market.

The reasons why other OEMs are not engaging actively with the technology are varied but include:

- An increased focus on the battery electric bus – there is a clear market emerging for battery electric buses. As this is a more mature technology with a clear market, manufacturers are tending to focus their vehicle development efforts on these vehicles.
- Limited size off engineering teams – the resource available for engineering within bus manufacturers is not as large as say for a passenger car OEM. These resources are stretched by making the base vehicles comply with Euro VI legislation and the range of other powertrains which could be considered. There is a limited engineering capacity and funds to move ahead with the fuel cell bus in the face of this competition for resources.
- Concerns over fuel cell technology and associated hydrogen infrastructure – an issue which is often raised is a concern that fuel cell stacks and hydrogen tanks will always be expensive and that the cost of hydrogen infrastructure is prohibitive.

Mitigating these issues and bringing more fuel cell bus manufacturers to the market is a challenge. Perhaps the most practical approach is to help create a market using the techniques described in the section above. This will create a market for those OEMs willing to commit to the technology, which in turn will create a competitive pressure and a confidence in the technology which will allow the more reluctant players to move forwards.

However, based on the issues raised by the reluctant OEMs, there are measures which could be considered to help encourage reluctant OEMs to market. These include:

- Working with potential component suppliers and the hydrogen industry to provide concrete examples and information on the cost base for a hydrogen drivetrain at volume.
- Making funds available to support prototyping activity for fuel cell buses to enable companies to touch and feel the technology and develop a commercial offer with which they can then develop their own market introduction strategies.
- Continued work to demonstrate the potential market and market dynamics for fuel cell buses when a reasonable manufacturing volume is achieved.

5.3 Next steps for cluster coordination

With the extension of fleets of fuel cell buses, especially in the JIVE and JIVE 2 projects, the cluster coordinators have shown that there is a growing interest in the use of such buses in Europe. The cities that are involved in the clusters have explained that they see a significant benefit from the support that has been provided by the cluster coordinators. In addition, they have declared their willingness to expand their bus fleets in the medium term and to make further and more intensive use of the hydrogen infrastructure being installed to fuel the initial fleets of buses.

This early push for the market is starting to result in commercial traction and some of the more dynamic players are beginning to develop their own initiatives to accelerate the sector and increase the volume of demand. However, the level of coordination implied by the requirements for the next phase of the market as articulated in sections 4.3 and 5.2 above suggest that there is merit in continuing to coordinate fuel cell bus demand. This coordination is required to ensure continued confidence amongst all stakeholders around the existence of the demand and to enable the demand-led cost reductions which are needed to bring the market closer to commercial viability.

However, for any further aggregation of demand to be successful in moving the sector away from the public sector and subsidy dominant phase of the JIVE deployments, several additional features can be recommended:

- A more direct link to private sector stakeholders – the cluster work so far has demonstrated that a good number of cities will consider limited fleets of fuel cell vehicles at a high price and with significant subsidy. The next phase needs to see cities gathered around lower priced vehicles, with lower levels of subsidy (i.e. more commercial sales). To support this the cluster managers will need to work with one or more suppliers to demonstrate the real viability of lower prices subject to achieving increased demand. Without this element of bringing manufacturers along as part of the demand creation it is unlikely that different results will be achieved from those presented here.
- Information provision for bus industry stakeholders – about the potential demand for the product and (perhaps more importantly) the potential suppliers and techno-economics of hydrogen drivetrains.
- Work with bus manufacturers not yet engaged to encourage prototyping activities to develop products for specific markets
- Unbiased market data to help support those developing commercial propositions for the market – this work should be based on market intelligence and should be clear about the cost requirements (e.g. for vehicle maintenance, hydrogen price) if the fuel cell bus is to achieve any unsubsidised market traction.
- Work with city level policy makers to encourage zero emission mandates and, where possible, pro-hydrogen route / operator tenders.
- Work with national level policy makers to propose subsidy schemes which can help hydrogen buses be competitive for bus operators. For example, in Germany funding within the NIP is secured until end of 2019 with a continuation of the programme until 2023. For a further future use of this programme, the cluster coordinators have already consulted the NOW. The funding level is currently 40% of the cost difference between a fuel cell bus and a diesel bus. In order to accelerate the conversion to clean buses, a funding programme for battery buses with a funding rate of 80% of the differential costs was notified to the European Commission by the Federal Ministry for the Environment (BMUB), which could possibly be applied to fuel cell buses too. As a funding instrument for fuel cell buses, this may create great momentum. Then the remaining problem is mostly the lack of availability of suitable buses. So, against this background, positive statements from a range of players in the bus industry indicating that they can provide such technically capable buses, ideally with an indication of price levels that can be achieved in the medium term, is

indispensable. This commitment can only be achieved through a joint European initiative and the FCH JU potentially has a role to play here by working on a bilateral and multilateral basis with key industry partners, with a view to allowing such public statements to be made. Only under this condition can it be assumed that the interest in fuel cell buses continues to grow.

- Local work to define the most appropriate hydrogen production and distribution options for each region.
- Developing funding applications for local support, ideally based on the demand-led concepts described above.
- Investigation of synergies with other emerging heavy-duty hydrogen vehicle applications such as trucks, refuse trucks and trains.

6 Dissemination

6.1 Context

The aim of the communications tasks in this project was to supplement the on-going dissemination activities of the FCH JU-funded demonstration projects to raise the profile of fuel cell buses across Europe. Shortly after the start of the phase of cluster coordination work covered in this report, the CHIC project ended and the JIVE project began. The conclusion of the CHIC project was marked with the highly successful Zero Emission Bus Conference held in London over two days in November / December 2016. Other relevant developments include the launching of websites such as *fuelcellbuses.eu* and *pers-ee.com/fr/mobhy/#/*, which provide information for planning fuel cell bus projects and a catalogue of vehicles available.

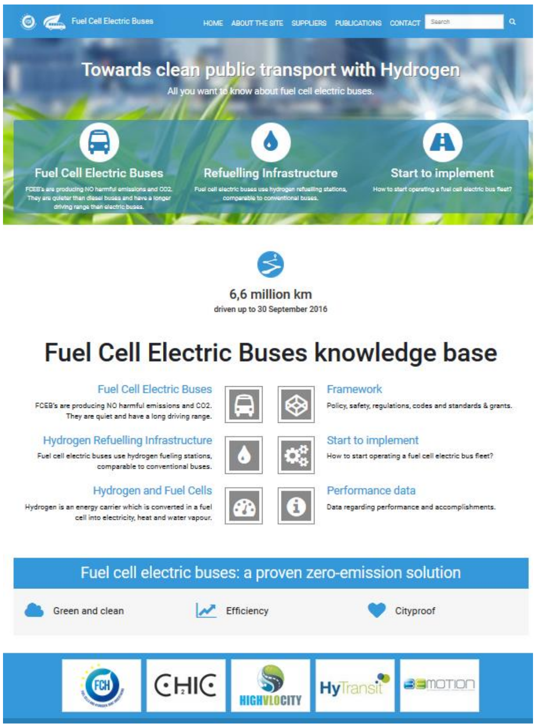


Figure 37: Home page of the fuelcellbuses.eu website[49]

6.2 Dissemination activities – highlights

The cluster coordinators represented the fuel cell bus sector at a number of conferences and events throughout this project; the most significant of which include:

- **Zero Emission Bus Conference** (London, November 2016) – the FCH JU's Executive Director presented the cluster coordination process and introduced the JIVE project at this major international conference (organised by Element Energy).
- **World Hydrogen Technology Convention** (Prague, July 2017) – Element Energy gave a keynote presentation on fuel cell buses at this gathering of hydrogen sector experts.

[49] Source: http://fuelcellbuses.eu/.

- **FCB CPH17 event** (Copenhagen, September 2017) – Element Energy was one of the principal speakers at this event, which was very well attended and designed to stimulate interest in fuel cell buses across Scandinavia and beyond.[50]
- **Connecting Europe Conference** (Tallinn, September 2017) – the Northern Europe cluster coordinator represented the fuel cell bus sector at this two-day conference held in Estonia.
- **EVS30 Symposium** (Stuttgart, October 2017) – the German cluster coordinator gave a presentation on fuel cell buses at the 30th International Electric Vehicle Symposium and Exhibition.

A full list of the principal dissemination activities carried out in this project is provided in the appendix (section 8.3).

6.3 Next steps for dissemination related to fuel cell bus activities

Despite the activities outlined above, the overall level of awareness of fuel cell buses amongst public transport authorities / operators remains relatively low. As demonstrated in section 2.2, there is much focus on battery electric buses as the primary zero emission option in this sector and proponents of fuel cell buses have further work to do to ensure that knowledge of the technology and its benefits continues to increase.

A coordinated package of dissemination work is planned as part of the JIVE projects, which should partially address this challenge. For example, a second addition of the Zero Emission Bus Conference is now being planned and is due to take place in Cologne on 27–28 November 2018.[51] However, there is a limit to the scope and effectiveness of what can be achieved via these projects, which essentially represent a group of customers for the vehicles. Building greater momentum in this sector will require a more active approach from OEMs, for example by presenting fuel cell buses at major industry conferences. While there is some evidence of this starting to occur (e.g. the launch of a fuel cell double deck bus by Wrightbus at the Zero Emission Bus Conference in late 2016), there is plenty of scope for more promotion of the hydrogen option by European bus OEMs.

In terms of the details of the messaging from the fuel cell bus sector, careful attention needs to be paid to communications to manage expectations and avoid hype, while increasing awareness of the development of fuel cell buses as a mainstream zero emission option from the early 2020s. There may also be a need to revisit the existing messaging / narrative to make it very easy for non-experts to understand the case for fuel cell buses.

[50] See http://hydrogenvalley.dk/white-paper/.
[51] See https://mailchi.mp/3941736d1dc3/save-the-date-zero-emission-bus-conference.

7 Conclusions

7.1 Demand for fuel cell buses from cities / regions

The overarching conclusion from this study is that demand for fuel cell buses from cities and regions across Europe remains robust and interest in the technology is growing. Approximately 90 different European regions / cities are currently showing a desire to understand the business case for introducing fleets of these zero emission vehicles and there is potential demand for over 1,500 fuel cell buses in Europe within the next few years. The first tranches of this next wave of fuel cell buses will be delivered through the JIVE initiative (the “JIVE” and “JIVE 2” projects), which together will support the roll-out and operation of nearly 300 buses in over twenty different locations. Turning the large potential demand figures into firm deployment plans relies on the successful delivery of these projects and continued coordination to realise the further cost reductions that industry has indicated are feasible.

Although the JIVE project formally began in early 2017 and joint procurement exercises in the UK and Germany got underway in the spring, by the end of the year negotiations with potential fuel cell bus suppliers were still on-going and firm orders for most of the vehicles had not been placed. The delays occurred for a variety of reasons, including the complexity of running joint procurement exercises, a lower than anticipated level of firm offers from suppliers, and external factors. Despite the delays, the outlook for the demonstrations planned in the JIVE project is positive since sufficient OEMs have confirmed their ability to offer buses that meet the FCH JU’s funding requirements (e.g. related to technology readiness and pricing (below €650k for a standard bus)), and some cities have already selected suppliers for vehicles and infrastructure (e.g. Pau, which is deploying a fleet of hydrogen-fuelled hybrid tram-buses for the first time in France).[52]

7.2 Fuel cell bus supply

The joint tenders run as part of the JIVE project sought to procure many tens of buses on a close to commercial basis. Given that few European OEMs have deployed large fleets of fuel cell buses to date, the industry response to this opportunity is perhaps unsurprising. Discussions with suppliers suggest that a growing number are preparing to offer fuel cell buses in the near future, but it is unlikely that the range of choice will match that available in the battery electric bus sector for many years. While this could be a threat to the further development of Europe’s fuel cell bus sector, it is also an opportunity for those OEMs prepared to supply vehicles and could be beneficial by focusing demand with a smaller number of suppliers and thus achieving greater economies of scale sooner (naturally, it is important to see sufficient suppliers in the market to create competition).

A further implication from the dialogue with bus suppliers is the potential need for further prototyping and demonstration activity for those new to this area. This suggests that the provision of grant funding to support such activities could help increase the number of OEMs offering fuel cell buses in the medium term.

While the overall number of bus OEMs prepared to offer fuel cell vehicles was lower than anticipated, several of those responding to this opportunity are optimistic about the

[52] www.eltis.org/discover/news/pau-france-introduce-fuel-cell-tram-buses-2019.

prospects for the technology competing with other zero emission options when sufficient scale and continuity of demand is established. Based on discussions with several European OEMs, a vision for the commercialisation of fuel cell buses and next steps required was developed and summarised in a White Paper produced as part of this study, which concluded:

- *Industry projections suggest that fuel cell buses will be competitive with battery electric buses on many routes within the next three to five years.*
- *Interest in battery electric buses from politicians in many cities has created market conditions that will allow fuel cell buses to compete economically without public sector subsidy.*
- *Fuel cell buses and battery electric buses are complementary technologies as they share a high proportion of common components; the most appropriate solution depends on the local context and constraints. With long range and short refuelling times, fuel cell buses offer a zero-emission solution on a wide range of routes, including high daily mileage, hilly terrain, etc.*
- *Continued development of Europe's fuel cell bus sector will require (i) technology-neutral zero emission policies in cities / regions and at a national level; and (ii) coordinated action to aggregate demands for vehicles that will unlock price reductions from economy of scale effects.*

7.3 Joint procurement of fuel cell buses

Although the formal joint procurement exercises have not yet been launched in all clusters (only the UK and German cluster have published joint tenders to date), the work undertaken in planning and running these exercises has created useful knowledge. A complete set of lessons learnt is provided in the main body of the report (sections 3 and 8.1), highlights of which include:

- The level of resource required to run a joint procurement exercise of the type implemented in the UK / German clusters should not be underestimated. There is a need for procurement experts, technical input (e.g. writing specifications), and legal advice as per any standard procurement for vehicles. In addition, time needs to be budgeted for coordinating between multiple councils / authorities and collecting input from a broad range of stakeholders (e.g. details of how bus specifications vary by city).
- A procurement strategy document that sets out the terms of reference for the group and responsibilities of all involved is required for these types of initiatives. Creation and agreement of such a document is generally the first step in any procurement process.
- Developing and agreeing a common basic specification for a fuel cell bus that is acceptable to multiple cities / operators is a considerable challenge. Ideally, full details of how the specification is expected to vary by customer (i.e. the requirements for optional extras and customised finishes) should be defined before a final decision on preferred supplier(s) is made.
- One of the important factors behind the success of this exercise has been early market engagement. Dialogue with potential suppliers was initiated early in the process and proved useful for informing suppliers of the emerging opportunity while allowing the buyers to tailor the process to maximise the chances of a desirable outcome.

7.4 Next steps for Europe's fuel cell bus sector

The *future planning* tasks undertaken in this study revealed that there is a strong and growing demand for fuel cell buses in cities across Europe, and that some bus OEMs and hydrogen suppliers have a desire to push the market into a commercial phase. Evidence from several European OEMs suggests that significant further cost reductions are possible at a scale of production of several hundred fuel cell buses per manufacturer per year, which could translate into 12m single deck vehicles priced at around €330k–€450k. On the hydrogen supply side, offers are emerging that could give an attractive economic and practical solution to bus operators (i.e. low footprint depot-based refuelling with renewable hydrogen at prices that give cost parity with diesel). Taken together, these developments imply that fuel cell buses could be the most cost-effective zero emission option on certain routes, and could therefore become the preferred choice in cities legislating against diesel-fuelled vehicles from the early 2020s.

Increased scale, both in terms of bus order numbers per OEM and fleet size per depot, will be crucial in realising these targets, as will continuity of demand as this is needed to bring about economies throughout the supply chain. The transition of this sector from large-scale demonstration projects to a commercial market is unlikely to occur without continued support and coordination in the short term. Recommended measures to bring about this change include:

- Coordination of ambitious, supplier-led deployment projects of the type described publicly in the Scandinavian hydrogen bus initiative, which is based on a direct link between commitment to large volumes and more attractively priced vehicles. This is a logical next step for the sector, in which commercial negotiations between suppliers and bus operators can begin based on a cost base that does not require large subsidies or risk-bearing public sector organisation intervention.
- Development of new mechanisms that help manufacturers manage demand risk – for example, guarantee funds that can effectively insure suppliers against the risk that demands fail to grow as anticipated and allow lower prices to be offered to customers earlier while passing on the risks and potential rewards to other actors better placed to carry this uncertainty. This type of concept is now being discussed and further work is needed to develop the idea into a structure that can be implemented in practice.
- A shift towards commercial offers from bus OEMs and hydrogen suppliers – expansion of the fuel cell bus sector will bring about the need for vehicles to be offered to customers in a way that is comparable to current incumbent technologies. This implies a requirement for new financing instruments for buses and the associated hydrogen refuelling infrastructure so that vehicles are available on a lease basis and fuel can be offered on a per-kilogram price basis without demands for high up-front capital contributions from bus operators.
- Dedicated hydrogen support in suitable locations – for example, cities that have experience with fuel cell buses and confidence that they can deliver cost-effective bus operations should consider favouring the hydrogen solution on a limited number of route tenders. Such a measure could help the industry overcome the initial scaling issues and ensure that fuel cell buses continue to be a viable option alongside battery electric buses.
- Use of subsidy programmes to drive the next phase of expansion of the sector – while the need for public funding will be reduced significantly at the price levels outlined above, the intelligent use of subsidies intended to stimulate this type of

market could accelerate commercialisation efforts. Options include European funding via the Connecting Europe Facility programme, and national support in markets such as the UK and Germany, where a zero emission bus incentive scheme is expected to be in place into the early 2020s.

8 Appendix

8.1 Procurement case studies

8.1.1 London, UK

Context

In 2014 a group of cities with an interest in deploying zero emission buses began collaborating on a programme with an overarching ambition to deploy approximately one hundred fuel cell buses by the early 2020s. Generally speaking, city councils in the UK are interested in fuel cell buses for similar reasons, primarily an urgent need to act to address poor air quality and commitments to reducing greenhouse gas emissions. The planned *Ultra Low Emission Zone* in London and *Clean Air Zone* in Birmingham, both of which will place strict limits on vehicle emissions by the end of the decade, are concrete examples of regulation providing a strong impetus for procuring zero emission buses.

The project was initiated at a time when the level of fuel cell bus deployment in the UK (and elsewhere) was limited – e.g. as of early 2015 there were just 18 fuel cell buses operating in the UK (ten in Aberdeen and eight in London). Furthermore, the choice of vehicles was very restricted, with only a small number of suppliers offering fuel cell buses and a limited model choice (single deck only). The UK's "*100 Fuel Cell Bus Project*" was conceived as part of a broader, Europe-wide effort to support the commercialisation of the technology, which included a project investigating options for joint procurement of fuel cell buses between cities with similar requirements.[53]

Process

The implementation of a joint procurement process for fuel cell buses followed three stages:

1) **Development of an approach to procurement** – in the first stage a working group comprising representatives of a selection of the interested cities was formed. Working with procurement experts, this group considered the advantages and disadvantages of a range of options for joint procurement, and narrowed down the options to a preferred approach.
2) **Preparation for procurement** – in the second stage the group developed the documents required to carry out a procurement process that complies with public procurement regulations. This involved consultation with bus operators and early market engagement with potential suppliers to collect information that informed the details of the procurement strategy.[54]
3) **Formal procurement** – the formal procurement process was launched with the publication of the invitation to negotiate in April 2017.[55]

[53] *Strategies for joint procurement of fuel cell buses*, Element Energy et al. for the FCH JU (June 2016). www.fch.europa.eu/publications/strategies-joint-procurement-fuel-cell-buses.
[54] For example, a request for information was published in January 2016.
See www.publiccontractsscotland.gov.uk/search/show/search_view.aspx?ID=JAN231981.
[55] The OJEU notice was published here: http://ted.europa.eu/udl?uri=TED:NOTICE:157506-2017:TEXT:EN:HTML&src=0.

April – Dec. 2015	Jan. – Sept. 2016	From April 2017
Develop approach to joint procurement	Early market engagement, develop procurement documents	Formal procurement

Requirements

The procurement process was developed to satisfy the following requirements:

- Facilitate the acquisition of hydrogen fuel cell buses by public and private sector organisations across the UK and beyond from 2017 to the early 2020s. This implies the need to comply with relevant procurement regulations and the policies of each partner involved.
- Allow the introduction of these vehicles into daily fare-paying passenger service over a period of many years. This implied the need for on-going maintenance support, and a mechanism to allow benefits of technology development and cost reductions to be captured.
- Aggregate demand for vehicles in the UK and coordinate with similar initiatives elsewhere in Europe to enable suppliers to scale up production and thus reduce costs in line with commercialisation targets.
- Accommodate a range of ownership structures to reflect the different models for delivering bus services in cities across the UK.
- Support the commercialisation of fuel cell buses by encouraging multiple suppliers to develop offerings, signalling the future demand for such vehicles, and creating competition that encourages new innovations and price reductions.

Options considered

The procurement working group that was formed as part of the *100 Fuel Cell Bus Project* considered various ways in which the procurement exercise could be run. The group quickly concluded that a fully compliant procurement exercise would be preferable to a less formal approach (such as a market test or partnering request). Despite the limited number of suppliers offering fuel cell buses when these issues were being considered (mid-2015), it was felt that an open, competitive procedure would be the most appropriate approach to (a) stimulate the market and (b) ensure best value for money.

Having agreed to run a full procurement process, the group then explored how this would be executed. The main options evaluated were:

- Joint procurement – i.e. combining the procurement actions of two or more contracting authorities (with one tender on behalf of all).)
- Simultaneous bilateral procurement – whereby each authority seeks to procure the same products but in a coordinated manner.

The joint procurement process was preferred as it lowers the risk of failing to achieve sufficient scale and offers efficiency benefits due to only needing to run one procurement exercise.

The structure of the joint procurement exercise then had to be considered. Again, several options were available:

- Lead authority approach – in which one authority takes the lead, with others feeding into the specification and evaluation phases.
- Specialist procurement agency – using an existing organisation that carries out joint procurement for public sector bodies (e.g. Crown Commercial Service, CMAL, Scotland Excel). While this was raised as an option, the consensus was that these types of organisations are better suited to procurement of commodities / utilities than innovative vehicles.
- New entity – forming a new legal entity could allow shared responsibility for procurement and give the flexibility for different types of organisations to procure vehicles on the same terms. Different variations of this option were also considered, e.g. an entity to simply carry out a compliant procurement exercise, through to the new entity procuring then owning and leasing the vehicles to operators.

The working group concluded that the lead authority approach offered a relatively simple, pragmatic solution and given willingness from partners within the project to take on the lead authority role, this was the chosen solution. In terms of type of procurement, the EU Public Contracts Directive (2014) defines five main award procedures:

- **Open procedure** – all interested parties may respond to OJEU advertisement by submitting a tender.
- **Restricted procedure** – includes a selection process for those who respond to the OJEU advert and only selected companies are invited to submit a tender for the contract.
- **Competitive dialogue procedure** – a selection of those who respond to the advert is made and the contracting authority enters into dialogue with potential bidders to develop one or more suitable solutions. It is on this basis that bidders are then invited to tender.
- **Competitive procedure with negotiation** – a selection of those who respond to the advert is made and only selected companies are invited to submit initial tenders for the contract. The contracting authority can then start negotiations with the tenderers to seek improved offers.
- **Innovative partnership procedure** – a selection of those who respond to the advert is made and the contracting authority invites suppliers to submit ideas to develop innovative works / supplies / services to meet a need for which there is no suitable existing product on the market. Partnerships may be awarded to more than one supplier.

Given the relatively limited number of suppliers able to offer fuel cell buses that will meet the required specification and the anticipated developments in the sector, the group chose the competitive procedure with negotiation.

Solution

The procurement approach taken involved Transport for London tendering to establish a framework of suppliers able to offer fuel cell buses in two “lots”:

- Single deck fuel cell buses.
- Double deck fuel cell buses.

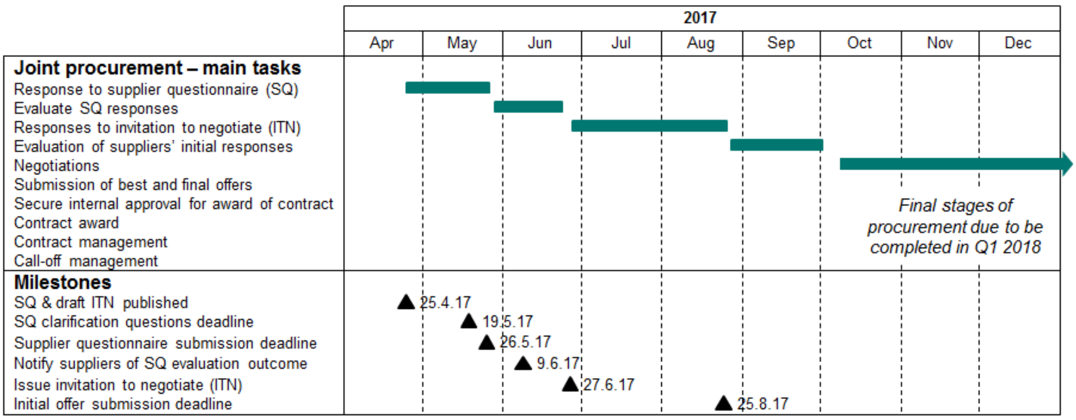
The rationale for forming distinct “lots” was mainly based on the desire to avoid inhibiting the potential supply base – i.e. some suppliers may be able to offer certain solutions only and the intention is to encourage as many as possible to offer suitable products.

The concept was to appoint qualified suppliers on to the framework via a competitive OJEU process, and then for vehicle orders to be placed via a series of mini competitions (“call offs”) amongst the appointed suppliers.[56] The framework will be in place for at least three years, with an option to extend by a further year. This provides a sustainable mechanism for on-going procurement of fuel cell buses over the medium term. The framework approach also aims to encourage continued development of the technology by manufacturers by allowing multiple suppliers to participate, thus avoiding the risk of creating a monopoly position and discouraging competition.

Other characteristics of the framework approach include:

- At the call off stage, contracts are put in place between the selected supplier(s) and individual authorities / operators procuring the buses. Although TfL runs the procurement exercise and manages the framework, TfL will not enter contracts for bus supply on behalf of other cities / regions.
- A series of call offs are envisaged throughout the life of the framework. The intention is to secure best value for money by enabling any cost reductions achieved as the sector scales up to be reflected in prices offered at different points in time.
- Provisions are in place to enable a wide range of public and private sector organisations to use the framework. While the exercise is designed around buses for the UK market, the option of organisations from other countries using the framework exists.

The formal procurement exercise for appointing suppliers to the first two lots was launched in April 2017 and followed the timescales below. Note that as of early 2018, negotiations with potential suppliers are on-going. The cities involved in the joint procurement process are planning to place the first order for buses during 2018.



[56] Note that the procurement arrangements also allow direct award of contracts for bus supply to selected suppliers on the framework.

Lessons learnt

The joint procurement exercise outlined above is on-going as of early 2018 and although the framework is close to being established, the first order for buses is yet to occur. Nevertheless, this approach to joint procurement is expected to lead to a successful result as multiple suppliers have confirmed their ability to offer vehicles that meet the required technical and commercial conditions. The following lessons can be drawn from the experience to date:

Overall approach to procurement

- One concept considered early in the process was based on selecting a preferred bus supplier before acquiring funding for the buses (from the FCH JU and other sources), and then entering into firm contracts for bus supply. The idea was that by working with a preferred supplier, applications for grant funding would be strengthened. However, the procurement working group concluded that it would be preferable to avoid committing to one supplier too early and that keeping options open would ultimately lead to greater competition and hence more attractive offers.
- An early conclusion of the procurement working group was that it is necessary to run a fully compliant procurement exercise for the buses given that (some of) the expected customers are public sector organisations.
- At one stage the group considered giving the lead role on procurement to a private sector bus operator, who could also conduct a compliant procurement exercise. The rationale for this concept is that large private operators purchase hundreds of buses per annum and are therefore well placed to use their purchasing power to achieve more attractive commercial terms. The group decided that on balance it was preferable to retain control over the process within the public sector bodies that are driving the fuel cell bus deployment initiative.
- The level of resource required to run a joint procurement exercise of this type should not be underestimated. There is a need for procurement experts, technical input (e.g. writing specifications), and legal advice as per any standard procurement for vehicles. In addition, time needs to be budgeted for coordinating between multiple councils / authorities and collecting input from a broad range of stakeholders (e.g. details of how bus specifications vary by city).
- The group also considered the option of jointly procuring hydrogen refuelling stations / hydrogen supplies, but concluded that given (a) the differing requirements in different locations and (b) the limited scope for economies of scale effects to reduce costs, it is more appropriate for cities to develop their own refuelling infrastructure plans.

Procurement process and timescales

- There is a need for a procurement strategy document that sets out the terms of reference for the group and responsibilities of all involved. Creation and agreement of such a document is generally the first step in any procurement process.
- It will have taken over three years from initially considering options for joint procurement to the first orders of buses. This is far longer than originally envisaged and not a timescale that others embarking on a similar exercise should seek to replicate. Delays occurred at various stages in the process and for many different reasons. For example, there was a change to the lead authority after the initial phase of work. There were also delays in issuing tender documents due to factors beyond

the control of the core project team.[57] Following the launch of the formal procurement exercise, the timescales had to be revised to account for constraints faced by the potential suppliers (e.g. summer factory shutdowns, availability of appropriate representatives to attend negotiation discussions).

- While delays in the procurement process caused some frustration amongst parties seeking to deploy the zero emission buses as soon as possible, there were some advantages to the extended timescale. For example, there was more time for the potential suppliers to develop their products and improve their offers, an important factor in a market such as this where one of the aims was to encourage new suppliers to offer new products. The delays also provided additional time for the cities to secure all the funding necessary to commit to purchasing fleets of fuel cell buses and to progress with plans for refuelling infrastructure deployment.
- One of the important factors behind the success of this exercise has been early market engagement. Dialogue with potential suppliers was initiated early in the process and proved useful for informing suppliers of the emerging opportunity while allowing the buyers to tailor the process to maximise the chances of a desirable outcome.

8.1.2 Cologne, Germany

Overview of approach

The approach to joint procurement in the German cluster was similar in many respects to the process followed in the UK, with one city leading a fully compliant procurement exercise on behalf of a consortium. Like in the UK (where there was potential demand for two main types of bus: single deck and double deck), the demand from cities in the German cluster required a mix of vehicle configurations: some standard (c. 12m long) buses and some articulated (c.18m long) buses. The main difference compared to the UK was that the German joint procurement exercise did not seek to establish a framework for on-going orders of buses, instead the German cluster plans to run follow-on procurements for additional buses as demands increase.

The joint procurement exercise for fuel cell buses in the German cluster was launched in May 2017. This exercise was led by WSW mobil GmbH (Wuppertal) and covered 63 fuel cell buses for operation in public transport. WSW coordinated the joint procurement for its partners Verkehrs-Verbund Mainz-Wiesbaden GmbH, traffiQ Frankfurt, Regionalverkehr Köln GmbH (all Germany) and SASA SpA-AG in Bolzano (Italy), which will operate these buses. The joint procurement was based on a common specification developed by the partners during late 2016 and early 2017. Within this activity functional differences in the buses and in the transport operation (topography, speed) were overcome to realise a largely standardised vehicle specification. In addition, the cities involved developed an assessment matrix for assisting in the evaluation of incoming offers. The tender was published in May 2017[58] and the deadline for responses was 14.00 CET on 19th June 2017.

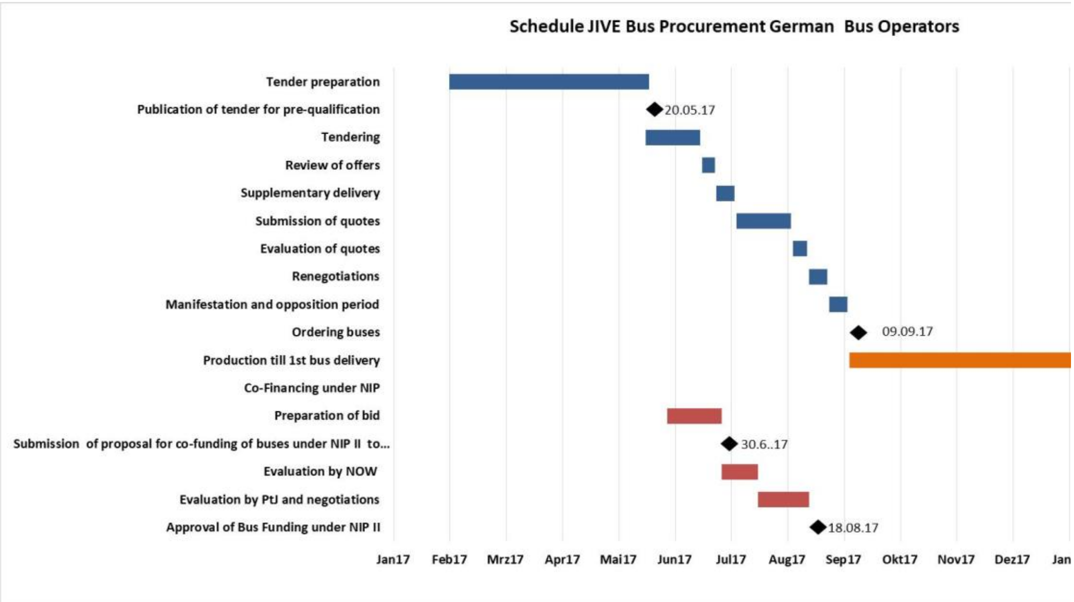
In parallel to this joint procurement exercise, preparations for the procurement of the necessary hydrogen refuelling stations started in each city. The operators began this

[57] For example, shortly before the planned ITN publication date (the point at which the tender documents, including the draft contract, were published), concerns over certain details in the draft contract were raised by legal experts reviewing the documents. Due to exceptionally high workload (from other areas of the business), the process of refining these details took several weeks.
[58] http://ted.europa.eu/udl?uri=TED:NOTICE:194439-2017:TEXT:DE:HTML&src=0.

process by considering the various options for hydrogen delivery or onsite production via discussions with several potential suppliers.

Timescales

The original timescales for joint procurement of fuel cell buses in the German cluster are shown below (upper Gantt chart). As the tender exercise progressed, it became necessary to revise the programme in response to the levels of responses received from potential suppliers, e.g. the negotiation period was extended and target date for ordering buses moved back towards the end of 2017. The latest schedule for the joint procurement exercise is shown in the lower Gantt chart below.



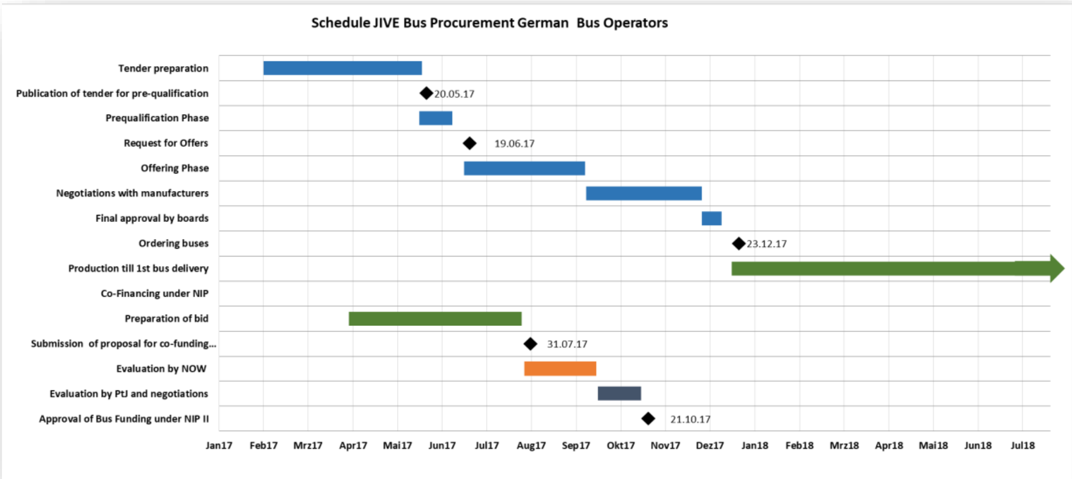


Figure 38: Timescales for joint procurement in the German cluster: original plan (upper chart) and revised schedule (lower chart)

Tendering for fuel cell buses in the German cluster took place in parallel to the UK cluster's joint procurement process. In both clusters the provisional timescales were revised after the publication of the ITT in response to feedback from potential suppliers.

Lessons learnt

Prior to the launch of the formal tender in May 2017, representatives of the German cluster contacted many of the major European bus OEMs as part of the early market engagement activities. The focus of the discussions with the manufacturers was on the question of when the next stage of development of fuel buses for everyday service can be expected. It was found that the development of battery buses is a priority both in time and in terms of development dynamics with most of the European bus manufacturers (Volvo, MAN, Daimler, Scania, Solaris). In this context, it is not expected that any of these manufacturers will be willing to provide the market with mature (pre-series) fuel cell buses before 2020.

Besides the problem with the delivery date the discussions also revealed that some of the manufacturers (OEMs) have changed their future vehicle concepts, with a trend towards offers being based primarily on battery buses, potentially with a fuel cell as range extender. Depending on the manufacturer, either battery (Daimler) or fuel cells (Solaris) are supposed to be used as the primary energy source.

Other insights gained from the German joint procurement exercise include:

- The number of OEMs prepared to respond to the formal tender in 2017 was lower than anticipated, with only two suppliers willing to provide vehicles and able to demonstrate an ability to satisfy all conditions of the tender.
- The main reason for this disappointing response appears to be that many of the incumbent bus OEMs in mainland Europe have not yet decided on the optimal technical solutions for zero emission buses. Given that these companies have limited engineering resources available, the current focus on battery electric buses appears to be restricting the rate of progress on the fuel cell option.
- Besides mature buses, a high level of local aftersales support needs to be available to allow the buses to operate reliably in daily operation.
- For a cluster-wide identical tender it is necessary to find a simple specification and at least a uniform bus. But since every customer has different requirements (topography, length of lines etc.) and wishes regarding the equipment (e.g. driver's working place, announcement system, number of seats, doors), joint procurement of an identical bus in the German public transport bus business is a larger challenge than expected.

8.1.3 Riga, Latvia

Context

Riga municipal limited liability company "Rīgas Satiksme" is responsible for all public transport in Riga and manages the city's public transport networks, with a fleet of 224 trams that operate on 9 tram routes and carried nearly 34.7 million passengers in 2014, 267 trolleybuses that operate on 19 trolleybus routes and carried approx. 47 million passengers in 2014, and 432 buses that operate on 53 bus routes and carried approx. 68.9 million passengers in 2014. The public transport network of "Rigas satiksme" (trams, trolleybuses, buses) runs a distance of about 45 million kilometres and carries nearly 150 million passengers a year. Due to the high mileage of the public transport and the architecture of Riga (with old canyon, tightly built streets, where the height of buildings is greater than the width of the road) there are problems with air quality as the pollutants do not readily disperse.

Riga City Council is taking serious steps to address the challenges of both decarbonisation and lowering of air pollution arising from transport in and around the city. In particular, the problem with local emission levels exceeding the EU-legislated maximum values has underlined the pressing need to move towards an emission free transport sector. Riga City Council has approved the "Riga City Sustainable Energy Action plan for Smart Cities 2014-2020" that estimates the basis for work towards a climate neutral provision of energy, gradually replacing public transport with zero emission vehicles (FCEV and BEV) to reduce the emission of CO_2 by 20% by 2020.

Riga typically purchases around 40 new buses per year and is developing plans for all new buses to be zero emission from 2018; including an ambition to deploy over 200 fuel cell buses within the coming years (most of which will be articulated vehicles). The fuel cell buses to be introduced as part of the JIVE project represent an initial step towards achieving this objective.

Status of (joint) procurement of fuel cell buses

Fuel cell bus project development activities in the Northern Europe cluster were coordinated by the Latvian Academy of Sciences and spanned an area including Denmark, Norway, Sweden, Finland, Estonia, Latvia, Poland and the Czech Republic. Of all the cities in this region interested in fuel cell buses, Riga had the most advanced plans and in its role as a partner in the JIVE project, Rigas Satiksme launched a public procurement in October 2016. This procurement exercise sought ten fuel cell buses (12m) as part of the JIVE project and ten fuel cell range extended trolleybuses as part of the Action "*H2Nodes – evolution of a European hydrogen refuelling station network by mobilising the local demand and value chains*" funded by Connecting Europe Facility. To date the contract has been awarded only for the fuel cell range extended trolleybuses part of the procurement. These vehicles were produced by Solaris and delivered to Riga in November 2017.

As of December 2017, negotiations between Rigas Satiksme and Solaris related to the 12m fuel cell buses are on-going. If both parties can agree on the commercial terms for supply of these additional ten buses (e.g. achieving pricing levels consistent with the conditions associated with the JIVE funding), an order for these vehicles will be placed by early 2018. If such an agreement cannot be reached, Rigas Satiksme will launch a new tender exercise in 2018.

Despite extensive efforts to develop a joint procurement approach in the Northern Europe cluster, it is unlikely that this type of procurement will be possible for various reasons (see below). Instead, a more pragmatic approach is expected to involve several parallel procurement exercises by cities from across the region based on a technical specification that is standardised as far as possible.

Lessons learnt

Compared to the other areas involved in this project, the Northern Europe cluster is unusual given the larger number of different countries (and very wide geographic area) represented. The work on supporting cities across this region with developing business cases and procurement plans for fuel cell buses revealed the following:

- Achieving the original ambition to establish a joint procurement approach encompassing all cities / regions in the cluster was fraught with difficulties arising from a combination of factors. These include differences in legal frameworks, languages, ownership arrangements, commercial structures, technical requirements, readiness to deploy fuel cell buses and levels of commitment to such projects between the different cities.

- Partners in the Northern Europe cluster considered using the UK framework for bus supply and although this remains an option in theory, in practice this is an unlikely procurement route given the differences in bus specifications and a lack of familiarity with suppliers on the framework amongst customers in the Northern Europe cluster.
- The fact that Rigas Satiksme was involved in live discussions with a potential bus supplier, and that there was a change in planned deployment city in Denmark in the JIVE project during 2017, hampered efforts to develop a joint tender for the first wave of JIVE buses in this region. As mentioned above, the most appropriate procurement approach in this cluster is expected to be based on a group of coordinated tenders with shared technical specifications. Further coordination and support of the cities is likely to be required to ensure that all cities in this region are ready to proceed with bus orders within similar timescales.

8.2 European bus OEMs offering / developing fuel cell buses

The table below summarises the experience of a range of European bus OEMs / suppliers in relation to fuel cell buses. Note that this is a non-exhaustive list.

OEM (country)	Relevant experience / products	Reference
Alexander Dennis (UK)	Working on a proof-of-concept hybrid fuel cell double-decker bus with Arcola Energy and Warwick Manufacturing Group.	https://cbwmagazine.com/adl-partnership-wins-funding-double-decker-fuel-cell-bus-concept/
ebe EUROPA (DE)	Offers 12 and 18 m buses ("Blue City Bus") based on Polish bus platform (by Autonova), acts as broker, no own production, REX-Concept. 	http://www.ebe-europa.com/ebe-europa-ueber-uns/?lang=en
EvoBus (DE)	Demonstrated 17 FC buses in the CHIC project, tens of FC buses produced to date. Releasing eCitaro in 2018 (E-CELL & FCELL technology). 	http://www.cte.tv/wp-content/uploads/2016/12/1_-Tuschen.pdf
rampini (IT)	Built the "H80" FC bus in 2007 (>3,000 hrs / 50,000 km covered). New FC bus "H120" being homologated. Plans to produce tens of FC buses over the coming years. 	http://www.rampini.it/en/products/hydrogen-ale-bus_19.html
Safra (FR)	Developing an FC version of plug-in hybrid electric buses of the "businova" –platform (10.5 and 12 m), REX-concept. 	www.safra.fr/fr/accueil/actualites/busworld-2017.html
SOLARIS (PL)	Two E18 FC buses in service in Hamburg. Ten FC range extender trolleybuses on order for Riga. Single deck products being offered on the Urbino platform. 	http://www.cte.tv/wp-content/uploads/2016/12/4_Michalak.pdf https://fuelcellsworks.com/news/solaris-articulated-trolleybuses-using-hydrogen-fuel-cells-to-run-in-riga
SOLBUS (PL)	First FC bus delivered to Syntus (Dutch bus operator) in mid-2016. 	https://fuelcellsworks.com/news/new-fuel-cell-bus-presented-in-arnhem-netherlands
URSUS BUS (PL)	Offers the "City Smile" 12m FC bus, based on a range extender concept. Demo bus present at the IAA 2016 (Hannover). 	http://ursusbus.com/; http://www.netinform.net/h2/H2Mobility/Detail.aspx?ID=547
VAN HOOL (BE)	>50 FC buses operating in Europe and the US as of Nov. 2017. Also offers articulated buses, 8 of which will be delivered to Pau, full-hybrid-concept. 	https://www.vanhool.be/ENG/actua/2fuelcellbuseslo.html
VDL BUS & COACH (NL)	Four articulated FC buses delivered in 2011 to Cologne and Amsterdam, 1 FC bus with formic acid reformer delivered to Eindhoven in 2017, 4 buses in 3Emotion (REX-Concept). 	http://www.vdlbuscoach.com/News/News-Library/Wereldprimeur--VDL-Bus---Coach-levert-de-eerste.aspx
WRIGHTBUS (UK)	8 single deck FC buses in London as part of the CHIC project. Single and double deck FC buses available for order from 2017. 	http://www.wrightbusinternational.com/news/news_item/WRIGHTS-GROUP-SHOWCASES-GROUND-BREAKING-HYDROGEN-FUEL-CELL-TECHNOLOGY

8.3 Record of dissemination activities

Cluster	Record of dissemination activities (2016/17)
Benelux	1. Busvision conference (13/10/16), Greater Utrecht Area. 2. Annual conference of the Dutch Hydrogen Association (01/12/16). 3. Fuel Cell Bus Workshop with Testrides, Cologne, 12th July 2017. 4. Power-to-Gas Event about the Synergy Project Hydrogen. Presentation on future upscaling in the Netherlands and the Northern Hydrogen Economy. Location Groningen.
France	1. Bus Working Group meetings: 24 November 2016, 4 January 2017, 15 February 2017, 29 March 2017, 11 May 2017, 4 July 2017, 29 August 2017, 6 October 2017, 27 November 2017 2. Planned Bus Working Group meetings: 16th January 2018, 6th March 2018, 18th April 2018, 24th May 2018 and 4th July 2018 3. First Hydrogen Bus Workshop (Bus Working Group members, French cities interested in H2 bus projects, public transport associations, joint buying associations): 24 May 2017.
Germany	1. EVS30 Symposium (9–11 October 2017, Stuttgart) – presentation given on October 9th 2017. 2. Presentation of the Fuel Bus Activities in Germany and Europe on a Bus Workshop in Cape Town (SA) on Feb. 21, 2017. 3. Presentation of the Fuel Bus Activities in Germany and Europe to Tokyo Metropolitan Government on Feb. 28, 2017 in Tokyo. 4. Participation on VDV Conference *Electric Buses in Urban Mobility*, March 7-8, 2017. 5. Fuel Cell Bus Workshop with Testrides, Cologne, July 12, 2017 (together with VDV), 120 participants from Germany and Benelux 6. Annual Meeting of the Fuel Cell and Hydrogen Network, NRW, November 30, 2017.
Northern Europe	1. HFC Nordic conference (26-27 October 2016, Sandvik, Sweden). 2. Regional Transport Investment Conference (23-24 March 2017, Sofia, Bulgaria). 3. FC bus event, Copenhagen (12 September 2017). 4. Connecting Europe Conference in Tallinn, Estonia, 21-22 September 2017
UK	1. *LCV 2016* (15/09/16) – MD presented on FC buses in Europe, including cluster coordination process. 2. *Zero Emission Bus Conference* (30/11/16) – cluster process and JIVE introduced by Bart Biebuyck (FCH JU). 3. *Hydrogen and fuel cells into the mainstream* (14/03/17) – Element Energy presented update on FC bus deployment plans in Europe. 4. *Eurotransport magazine article* (May 2017) – linked to the JIVE project. 5. Call to discuss FC bus deployment in India with German cluster coordinators (19/05/17). 6. The 7th World Hydrogen Technology Convention (9-12 July 2017, Prague, Czech Republic) – MD presented cluster work and commercialisation path for FC buses in Europe (10/07/17). 7. FC bus event, Copenhagen (12 September 2017) – BM gave keynote address. 8. Hydrogen workshop (*A Role for Hydrogen in the Decarbonisation of the Irish Energy and Transport Systems?*), Dublin (03/10/17) – MD presented on FC buses.

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