# Strategies for joint procurement of fuel cell buses

A study for the Fuel Cells and Hydrogen Joint Undertaking





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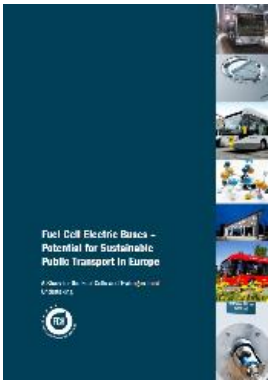
# 1 Executive summary

## 1.1 Context

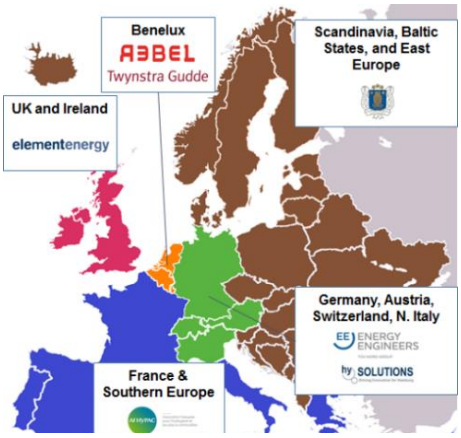
The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has supported a range of initiatives in recent years designed to develop hydrogen fuel cell buses to a point where they can fulfil their promise as a mainstream zero emission vehicle for public transport. Notable examples include:

- 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.

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



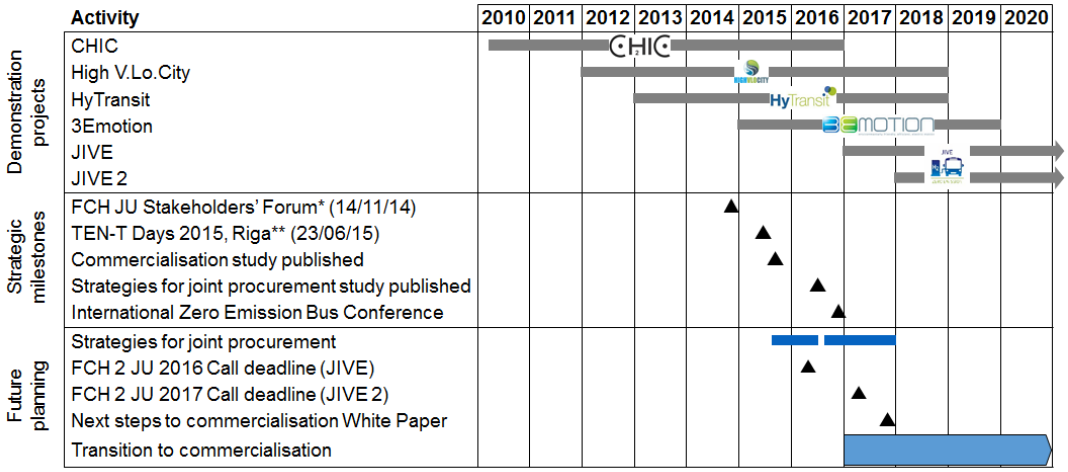

- A commercialisation process for fuel cell buses – the FCH JU funded a collaborative process involving industry representatives and potential customers for zero emission buses that led to the publication of the *Fuel Cell Bus Commercialisation Study* in 2015.[1] This report set out a vision for commercial 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.




*Geographic scope of the cluster coordinators in this study*

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

[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.

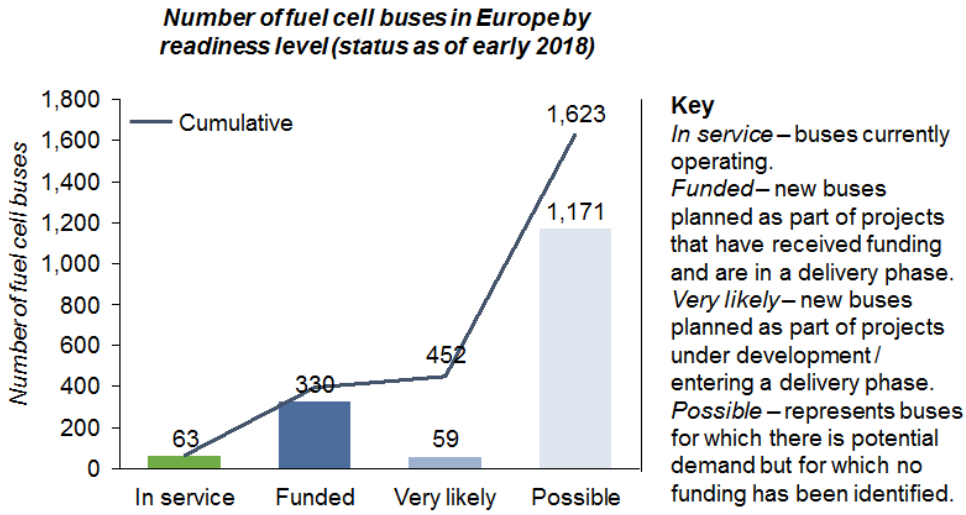



**Figure 2: Number of fuel cell buses in service, planned for deployment ("Funded" / "Very likely", and potentially demanded ("Possible") across Europe**

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 developed for further fuel cell bus projects (*JIVE 2*). However, the joint procurement

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

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

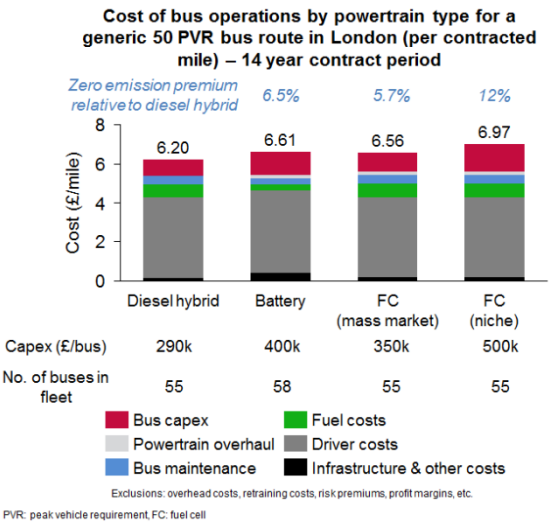
In addition to working with cities / regions to develop business cases for fuel cell bus deployment in the short term, the cluster coordinators examined the potential for larger scale uptake of this technology in Europe in an unsubsidised, commercial phase beyond 2020. This *planning beyond the subsidised 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.