# JIVE Final Best Practice and Commercialisation Report (D3.26)

Klaus Stolzenburg, Katharina Buss

# JIVE 2 Final Best Practice Information Bank Report (D3.29)

Nicole Whitehouse, Simon Whitehouse

ZERO EMISSION

**JIVEs / MEHRLIN projects**

@fuelcellbus www.fuelcellbuses.eu

Clean Hydrogen Partnership

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Main authors: Klaus Stolzenburg (PLANET) k.stolzenburg@planet-energie.de (JIVE)
Katharina Buss (PLANET) k.buss@planet-energie.de (JIVE)
Nicole Whitehouse (Sphera) NWhitehouse@sphera.com (JIVE 2)
Simon Whitehouse (Sphera) SWhitehouse@sphera.com (JIVE 2)

Contributors: All sites via their questionnaire input and via discussions in project meetings and bilaterally

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# Summarising Case Study

It is difficult to put together a summary of a series of Best Practice suggestions for implementing this new bus propulsion technology. What do you mention – what do you leave out? By its very nature, Best Practice cannot be shortened to a few summary paragraphs.

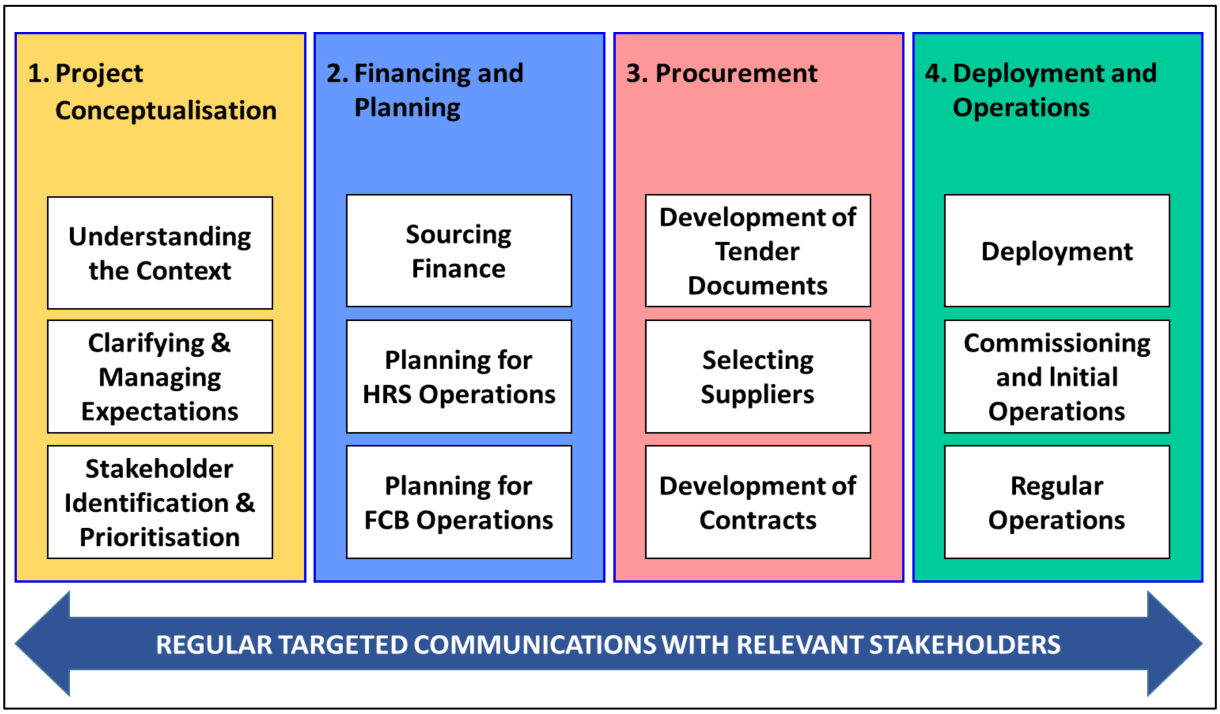
Therefore, in the place of a summary/conclusion, this section provides a Case Study of what a Best Practice Fuel Cell Bus (FCB) implementation project might look like. This 'perfect world' scenario is based on a range of 'real world' examples and the experience and imagination of the authors. It brings together in a narrative many of the key Best Practice recommendations regarding FCBs and Hydrogen Refuelling Stations (HRSs) gathered from JIVE/JIVE 2 project partners and knowledgeable others. This is an 'ideal' scenario and should be interpreted as such, serving only as a vehicle to highlight approaches that work. It can be considered an 'appetiser' to the full document which contains much more detailed insights.

If there is one piece of wisdom that does transcend all practices, it would be that all contexts are different, so the advice that you find in this case study, the full document and in other resources needs to be considered in the light of your own project and its specific circumstances. Having said that, there is some good advice here for every situation.

## Setting the Scene

The year is 2024 and in European City X the local council has decided that due to the twin imperatives of improving air quality and meeting EU $CO_2$ emission standards and allied policies, public transport buses would need to move to fully emission free alternatives from 2030 onwards. As part of the region's decision to develop a hydrogen-based energy system, the local administration decided to acquire Fuel Cell Buses (FCBs). These decisions had strong and widespread political and community support.

Based on Best Practice work undertaken in FCB demonstration projects with sites across the EU, they decided to follow the Stages approach developed during these earlier activities.




**Stages and sub-stages of a project to demonstrate Fuel Cell Buses and their hydrogen fuel infrastructure.**

## Stage 1 – Project Conceptualisation

The Mayor of the City tasked the CEO of the Public Transport Authority (PTA) to make this happen. The CEO appointed an experienced senior member of staff as project leader to source funding and implement a programme to deliver the outcome. The project leader had significant experience in transport policy and working with teams to deliver projects. She established a dedicated Project Team of three full time workers consisting of herself, a technical person with a good understanding of bus technology, some knowledge of alternative energy technologies and good networks and linkages with the Public Transport Operators (PTOs) active in the city, and a legal expert in the area of tendering and contracts.

A Project Steering Committee was also set up consisting of the Mayor, the CEO of the PTA, the Chief Operating Officer of the PTA, a senior financial officer tasked with supporting the project, a senior engineering staff member and a senior marketing person in the PTA. The project leader asked for and gained their commitment to attend regular briefings, particularly in the early months of the project.

### Understanding the Context / Clarifying and Managing Expectations

The Project Team started with developing a vision that set the project within the context of the city's regional and national forward strategic plans. This included strategic use of sources of renewable energy, the relevance to local industry and to national and supra-national requirements to meet clean air and climate change targets. Examples of what was considered included:

- A thorough explanation of the policy environment driving the decision to invest in new clean technologies
- A consideration of the energy system (stationary and transport) and how the introduction of the new renewable energy might be leveraged in this setting (e.g. hydrogen as a buffer for intermittent renewable energy)
- The chance to create synergies with local/regional/cross-regional industry (manufacturers; gas suppliers etc.; by-product hydrogen from chemical plants etc.; pooling hydrogen demand with other (large) consumers to achieve better prices)

The vision developed was complemented with a description of outcomes/benefits that might be expected to be derived from the new technology. These were updated as the project developed (e.g. from business case analysis).

### Stakeholder Identification and Prioritisation

In parallel, key stakeholders in the community and their areas of interest were identified. Significant among these were local PTOs that showed interest in being part of the project.

A Stakeholder Map was drafted and kept up-to-date during all Stages, and a first Communication Plan was developed and implemented.

**Important points to note from the story:**

1. Advantage: Highly influential political support;
   Risk: Political climates can change quickly and dramatically;
   Solution: Make a robust case that appeals across the political field and to other key community stakeholders
2. Appoint experienced, dedicated project staff with a good spread of existing experience and skills needed for this project
3. Develop a broader vision for the project
4. Identify stakeholders early, co-opt all the important players including a spectrum of political actors, and establish mechanism for regular, targeted stakeholder communication

## Stage 2 – Financing and Planning

With the project vision in place, the Project Team undertook an intensive period of familiarisation with all aspects of the task ahead. This included:

- Enhancing their understanding of all aspects of bus operations in their city, including tender and funding cycles, and dialoguing with the interested PTOs. Selection of a PTO to partner on the project occurred during the Planning Stage.
- Reviewing reports from past and ongoing FCB implementation projects
- Visiting other cities that had already gone down the route of FCB acquisition which included gaining an understanding of the reasons behind their chosen refuelling arrangements (e.g. procuring and operating the HRS themselves and obtaining the fuel from a regional supplier of renewable ('green') hydrogen, or buying fuel at the nozzle/'hydrogen as service' with a third party owning and/or operating the HRS)
- Meeting with suppliers selling FCBs and suppliers of HRSs and/or hydrogen, and conducting a more formal Request for Information (RFI) process to test the market
- Engaging an expert to develop a list of possible funding sources to cover the additional costs incurred by the new technology together with advice on the best 'fit for purpose' to approach

Tasking marketing & communications support with developing a targeted and detailed Communication Plan based on the refined Stakeholder Map and in line with each Stage of the project.

This information was fed back to the Project Steering Committee in the regular briefings. Concerns/issues raised by the Steering Committee were rigorously addressed.

Based on the significant familiarisation research undertaken, the project team drew up the broad outline of an implementation plan that detailed:

- Proposed numbers of FCBs
- Proposed refuelling arrangements including proposed location of the HRS
- Proposed FCB operator/PTO

**Further important points to note from the story:**

5. Spread the information gathering net wide enough; importantly include suppliers and experienced cities; potentially use a RFI process
6. Speak to PTOs early to provide them with information and to understand their perspectives; once operator of FCBs is selected directly involve them with scoping out their requirements
7. Undertake dedicated work to find possible additional funding sources
8. Maintain political and community support by attending to issues raised

Concurrently, work had also commenced on the business case for the FCBs. The PTA's finance staff were fed information gathered in the early planning stages. This business case was developed using conservative estimates for costs and, where costs were uncertain, to assume the upper end of the range. This was to reduce risk of budget 'surprises' at a later date.

FCBs were compared with battery electric buses (BEBs) and also with non-zero emission internal combustion engines (diesel and natural gas). The intent was to make a thorough case for FCBs over the long term, on the grounds of cost, operations and synergies with other regional hydrogen use options.

The Project Team understood that covering the likely additional immediate costs of the new technology when compared with diesel and battery electric buses was essential to getting buy-in from their selected PTO. As a commercial enterprise, the PTO would be looking to de-risk the process of moving away from what they know and expect support from the PTA to do so. This de-risking process included an assured hydrogen fuel supply at a fixed price over a certain period.

As part of this process, other cities with experience in FCB acquisition were approached again, to help advise on various business case aspects. The time horizon for the business case was built around the typical 10 – 15 years replacement cycle for diesel buses. The business case covered CAPEX and OPEX, including 'beyond project' costs to be expected to arise after a co-funded initial phase.

### Calculating the Additional Costs

CAPEX: The still existing relative lack of competition among FCB and HRS suppliers, and therefore likely higher costs, was included in the cost estimation process.

OPEX: The PTA guaranteed the PTO a hydrogen fuel price resulting in fuel costs per kilometre driven that are equivalent to using diesel.

Consideration was given to augmenting the volume of hydrogen required by assuming conversion of city administration's fleet of vans, refuse collection trucks etc to fuel cell vehicles which could assist in securing a lower price for the hydrogen through higher volumes. However, this had to be balanced against any resulting increased CAPEX. FCB and HRS maintenance costs were estimated taking the same conservative approach described above.

While the CAPEX and OPEX calculations (and therefore the Total Cost of Ownership), took account of the likely direct financial costs to the PTO and the PTA, to present a more profound case the broader community benefits of moving to zero emission buses were also considered, in terms of a Life-Cycle Costing approach. These included financial savings from reduced human health costs from fossil fuel emissions, as well as improved public amenity from reduced noise, more comfort and public approval. The project team knew these would provide a good argument for asking for additional funds if necessary or, in the future, cheaper loans from government (or their funding/financing organisations) for whom health costs are a large budget item.

### Covering the additional costs

Following costing calculations and the funding research being finalised, proposals were submitted to cover the additional costs from sources outside the usual bus fleet and infrastructure investment programmes. Funding requests were audited for conflicting requirements between different funding bodies, and with private-public rules in mind.

Once all planning – technology, communications, financing outcomes – were in place and funds approval obtained, a decision was made to go ahead with procurement.

**Further important points to note from the story:**

9. Continue to seek support from experienced others
10. Ensure conservative cost estimates, address additional funding requirements and the need to de-risk in order to achieve PTO buy-in
11. When seeking funding for additional costs, be aware there can be conflicting requirements from funding sources
12. Plan for going over budget and over time
13. Consider undertaking a Life-Cycle Costing exercise
14. Respond to short deadlines (e.g. to meet co-funding requirements) by running concurrent activities

## Stage 3 – Procurement

HRS and FCB tenders were dealt with concurrently but separately. Expert groups were formed with membership being specific to the technology. One expert group (mainly drawn from the PTA) would manage the HRS tender, and the other (led by the PTO) would manage the FCB tender process. Some overlap in personnel was built in to ensure both groups were kept informed of the others activities. The timing of the calls was designed to try and have both FCBs and HRS commissioned at the same time, but was also consistent with the investment cycle of PTA/PTO to take advantage of existing and proven procurement processes and to work in with city's budgeting arrangements.

To address potential reservations by local authorities lacking experiences, an early professional safety assessment for the HRS and the bus maintenance facility was arranged and the outcomes fed into the tender documents.

### Developing of Tender Documents for the HRS

The HRS tender was run by the PTA. PTA staff had had the opportunity to gain their expertise during the project planning process and had already determined the location of the HRS, in agreement with the PTO. The designated area provided the likely required footprint space, including space for future scale up.

The tender document emphasised performance outcomes wanted, rather than specifying inputs. Requirements for *dispensing* capacity during a daily refuelling window of some hours (rather than the size of the hydrogen *storage*), modularity and scalability, precision of hydrogen metering and hydrogen quality assurance (purity) were addressed. Potential suppliers were encouraged to be innovative and given thorough briefings consistent with procurement regulations.

It had been decided that the PTO would own and operate the HRS. Therefore, regular and backup hydrogen supply had also to be tendered for.

Tenderers were strongly encouraged to visit the proposed HRS location and to speak to FCB manufacturers to understand their latest technology (e.g. the need to pre-cool hydrogen for Type IV tanks; Bus-to-HRS communication through infra-red connections etc).

### Developing of Tender Documents for the FCBs

The PTO was in the process of purchasing new buses and the procurement of FCBs was added into their normal tendering arrangement. Alternatively, a specific, one-off tender arrangement would have been possible, if the PTA had required.

The PTO was able to use their existing bus tender template as a base and integrate into it the *outcomes*-based performance criteria for the FCBs. To define these criteria, they had spoken to experienced cities, researched publicly available performance data on the technology and tested draft criteria with potential suppliers through an RFI.

Selecting Suppliers / Development of Contracts

Prices offered were higher than wanted for the HRS. The final price was negotiated with the preferred supplier during the contracting process. In relation to the hydrogen supply, the PTO was able to offer a guaranteed length of contract with break clauses. Issues to do with ownership, responsibilities, operational data to be logged and provided, guarantees & warranties, penalties and the coverage of 3rd party suppliers (such as the manufacturer of the hydrogen compressors, being key/critical components) were all addressed in the development of the contract.

The limited FCB supplier market yielded only two proposals. The PTO remained flexible in negotiating the FCB price with the preferred supplier, leveraging possible alternative maintenance and training arrangements and possible future purchases to deliver an acceptable price. Due to additional funds available from the PTA for the introduction of the new technology, the PTO was comfortable that their commercial operations were not at risk.

**Further important points to note from the story:**

15. Run tenders in parallel but not necessarily by the same organisation
16. Tenders should concentrate on outcomes wanted; include scalability as appropriate
17. Purchasers should remain flexible in order to meet cost limits
18. Ownership of assets and responsibilities should be made explicit in the contract as should access to operational data and penalties for non-performance
19. An early professional safety assessment of HRS and bus maintenance facility provides comfort to local regulatory authorities and supports the tenderers

### Stage 4 – Deployment and Operations

Deployment

Once the procurement contracts were signed, the Project Team focus turned to preparatory activities that need to be undertaken before operating FCBs can commence. A timeline for delivery of the buses and the availability of refuelling had been agreed as part of the contracts. Some buffer was built into the timelines to manage any delays and also to ensure the stakeholder expectations were realistic.

Due to high demand, the lead time for the FCBs was 12 months. The HRS was contracted to come online ahead of the buses to allow for refuelling and testing the first buses on arrival.

*HRS*

Site preparation work began as soon as possible. The site was close to, but not on the bus depot where the FCBs would be located. This was to facilitate refuelling in the timeframe acceptable to the PTO. The HRS also allowed for the possibility of scale up and for refuelling of other types of FC vehicles (cars, waste trucks etc.) at different pressures.

*Bus Depot*

Upgrade of the bus depot also needed to occur to both prepare maintenance arrangements and parking space so that e.g. safety requirements were adhered to. This included configuring the depot so that the FCBs and their battery electric and diesel counterparts in the fleet did not interfere with each other, e.g. in terms of refuelling/charging. A lot of the thinking work on this had been done by the Project Team with the PTO at the Planning and Financing Stage, again with an eye to future needs for a fully zero emission fleet. The PTO had been provided with a grant to undertake this extra work and controlled the contracts to make it happen.

*Route Checking*

The PTO had also already identified the inaugural routes for their new buses. These were to be 'long run' routes ideally suited to FCBs with their range and flexibility. Two buses were to be dedicated to the "Clean Air" zone in the heart of the City to give the new technology good visibility. Methodical checking of these routes now commenced in order to identify any unanticipated hazards for the somewhat taller (FC equipment on the roof) and heavier buses. This check would be repeated just prior to the buses coming into operations and emphasised in bus driver training.

*Awareness Raising and Training*

The PTO and the PTA also worked together to schedule awareness raising and training for all the different groups of people coming into contact with the buses. These included:

- Maintenance technicians
- Drivers
- Refuelling/Cleaning staff
- All depot staff – with particular emphasis on safety

- First responders (Emergency Services)
- Regulatory /Permitting Authorities
- General Public

Refresher training was scheduled for those most involved to pick up on new employees. In the case of the latter two groups, advance awareness raising had been in place since the Planning and Financing Stage was completed and the Procurement process had commenced.

As part of the contract, the bus supplier had agreed to a “Train the Trainer” arrangement where initial training was undertaken by the supplier and would be taken over by the PTO over a period time. Full documentation would be provided to the local trainers and a staff member of the bus supplier would remain available to the local people for support for an additional year as part of the contract. The same approach was taken for the HRS with respect to refuelling personnel.

The groundwork for obtaining permits for the new facilities had been laid as part of the communications strategy in the Planning Stage. Activity in this area now picked up pace, with support from the FCB and HRS suppliers.

### Commissioning and Initial Operations

Despite every effort to synchronise the commissioning of buses and the HRS, the latter was delayed due to permitting delays. Backup refuelling arrangements (a temporary “mobile” refueller) had already been planned and were swung into action to coincide with the arrival of the first FCBs. As part of preparation of the community for the introduction of the FCBs, a press release featuring photos of the new buses was released.

*FCB Commissioning and Testing*

Bus acceptance testing was carried out close to the intended depot and included the range of topography over which the bus would run. Suitability of route was thoroughly tested and a note made to driver training that the FCBs were not to be run on unauthorised routes, for example due to their increased height. Some standard components were found to be faulty and quickly remedied by an on-site technician from the bus supplier using the onsite stock of spare parts. The time taken for these checks was longer than for a typical diesel bus, but this had already been factored into the planned start date of operations, as had the necessary training of drivers and technicians.

A “fire onboard a bus” simulation exercise was carried out involving the City first responders and relevant depot staff including drivers.

Onboard data collection and delivery systems specified by the contract were tested and found to be adequate. The bus and HRS supplier were contractually obliged to resolve any inconsistencies in readouts and were able to successfully achieve this to meet the needs of PTO.

As part of a feedback system to their production line, the bus manufacturer retained their technician at site for a pre-specified period to give immediate notice on identified faults. At the same time, hands on learning was provided for the PTO bus technicians.

*HRS Commissioning and Testing*

Despite the delays already experienced, the Project Team ensured that the HRS supplier followed the planned ramp-up once it was ready to commence operations. This allowed identification and resolution of faults as they arose and gave an indication of where future issues may arise, informing what additional spare parts may need to be kept in storage locally. Hydrogen quality to the nozzle was tested as were hydrogen pre-cooling and redundancy systems. The supplier's onsite technician was able to handle all issues within the contract-specified half day timeframe.

During this ramp up period, FCB refuelling staff were also trained in understanding the system and their role in it and the HRS alarm system was tested through a simulation exercise which was to be repeated regularly in the future.

Refuelling times were verified and found to be adequate with the pre-cooling in place. However, HRS data was not forthcoming as per the contract due to software errors. These were resolved and penalty clauses did not have to be invoked ahead of regular operations.

### Regular Operations

Having done a slow and methodical ramp up of buses and the HRS, the buses went into regular operations in a seamless fashion. The PTO had plans in place for backup diesel buses to be available for the first 3 months of regular operations should the FCBs have operational problems. These were accessed a couple of times due to driver concerns about dashboard error messages suggesting malfunction of an FCB. All were found to be software issues and remedied without major loss of availability. The speed of fault resolution was partly due to a contractual arrangement on timely communications between a well-trained local technician and an "on call" technician at the bus manufacturer.

The City administration took the opportunity of the arrival of the buses to hold a public event to welcome the buses and to raise awareness about their benefits at a local and wider level. A video of local dignitaries on one of the buses was released and run on local news channels.

Drivers, technicians, PTO administrations and the public were surveyed after a period of 6 months to gauge level of acceptance. Results indicated there was a high degree of satisfaction with the quiet and smoother ride among the public and with the ease of handling among the drivers. The PTO administration was highly satisfied with the fuel efficiency, the reliability and the reception of the buses by the public.

Performance of the HRS was not as good. It suffered numerous shutdowns during the first 6 months period. These were generally due to compressor failure and, initially, software problems. These situations were mitigated greatly by the contractual backup hydrogen delivery and storage service. The site having invested in a hydrogen trailer facility were able to use it as a mobile refueller. The bus tanks were often not filled to the desired level or the fills took longer than guaranteed. This, too, was mitigated by software adjustments tailoring the refuelling protocol.

An unexpected rise in electricity prices led to a significant increase in the per kilogram cost of hydrogen. The PTA had contracted to cover price rises above a certain amount to de-risk this aspect of the OPEX to the PTO.

Finally, while the site subsequently decided on increasing the number of FC buses in their fleet, there was agreement that another HRS would be a necessary component (to give ultimate redundancy and secure backup) and that interesting a supplier to tender to provide hydrogen at the nozzle (‘refuelling as a service’) might be a preferred mode of procurement.

**Further important points to note from the story:**

20. The rapport you have built up with suppliers both on the bus side and the refuelling side will be invaluable once regular operations begins. Communications between bus and refuelling contractors should be facilitated as part of good communication between all parties
21. Rigorous planning (including contingency planning) and contractual comprehensiveness will avoid or mitigate most of the typical challenges experienced in the Deployment and Operations Stage
22. Unexpected challenges will be easier to handle by building buffer into your timeline and your budget for regular operations. You must expect delays and increase in cost.
23. Have backups in place, both for the buses and for the HRS. While buses are very reliable by the standard of new technology, they will likely have teething issues as will the HRS
24. **Good Training and Maintenance = SAFE Operations**
25. Leverage the buses for showing the public you will be meeting European emission standards. It will encourage the use of public transport and be a source of pride for the municipality and region.

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# List of Abbreviations and Terms

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| BEB | Battery Electric Bus, sometimes referred to as 'battery-only bus' because a Fuel Cell Bus also carries a small battery that supports the fuel cell and recovers energy when breaking |
| CAPEX | CAPital EXpenditure |
| CEF | Connecting Europe Facility |
| CHIC | Clean Hydrogen in European Cities, project co-funded by the FCH JU under the 7th Framework Programme (2010 – 2016) |
| CVD | Clean Vehicles Directive – Directive 2019/1161 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles |
| EIB | European Investment Bank |
| EU | European Union |
| FC | Fuel Cell |
| FCB | Fuel Cell Bus (an electric bus powered by a fuel cell that runs on hydrogen fuel, supported by a small battery for e.g. energy recovery) |
| FCH JU | Fuel Cells and Hydrogen Joint Undertaking, first phase of the FCH JU under the EU 7th Framework Programme; abbreviation also commonly used for the FCH 2 JU |
| FCH 2 JU | Fuel Cells and Hydrogen 2 Joint Undertaking, second phase of the FCH JU under the EU Horizon 2020 Framework Programme; the FCH 2 JU was re-launched in 2021 as the Clean Hydrogen Partnership |
| FMECA | Failure Mode Effects and Criticality Analysis |
| GHG | GreenHouse Gas |
| $H_2$ | Hydrogen |
| HRS | Hydrogen Refuelling Station |
| HyFLEET:CUTE | FCB Demonstration Project co-funded by the FCH JU under the European Union's 6th Framework Programme (2006 – 2009) |
| HyTransit | European Hydrogen Transit Buses in Scotland, project co-funded by the FCH JU under the 7th Framework Programme (2013 – 2019) |
| JIVE | Joint Initiative for Hydrogen Vehicles across Europe, project co-funded by the FCH 2 JU under the European Union's Horizon 2020 Framework Programme (2017 – 2022) |

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|---|---|
| JIVE 2 | Second Joint Initiative for Hydrogen Vehicles across Europe, project co-funded by the FCH 2 JU under the European Union's Horizon 2020 Framework Programme (2018 – 2023) |
| LCC | Life-Cycle Costing, takes in account, in addition to the Total Cost of Ownership, costs related to environmental externalities; these may include the cost of emissions of greenhouse gases and of other pollutant emissions and mitigation costs (climate, health …) |
| MEHRLIN | Models for Economic Hydrogen Refuelling Infrastructure, project – co-funded by the European Commission's Connecting Europe Facility (2017 – 2022) |
| NGO | Non-Governmental Organisation |
| OPEX | OPerational EXpenditure |
| PTA | Public Transport Authority |
| PTO | Public Transport Operator |
| RED II | Renewable Energy Directive II – Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) |
| RFI | Request for Information |
| TCO | Total Cost of Ownership, includes the CAPEX and OPEX over the life cycle of a product, service or works |

# 0 How to Use this Document

Increasing numbers of local and regional governments are requiring public transport bus operations in their jurisdictions to be locally emission free in the near future. Hydrogen Fuel Cell Buses (FCBs) are one option that can achieve this outcome. The Clean Hydrogen Partnership has provided funding to the JIVE and JIVE 2 projects to support the deployment and commercialisation of FCBs, including their Hydrogen Refuelling Stations (HRSs).

The JIVE/JIVE 2 deployment sites are shown in Figure 0-1. More detail on the projects can be found in 0.

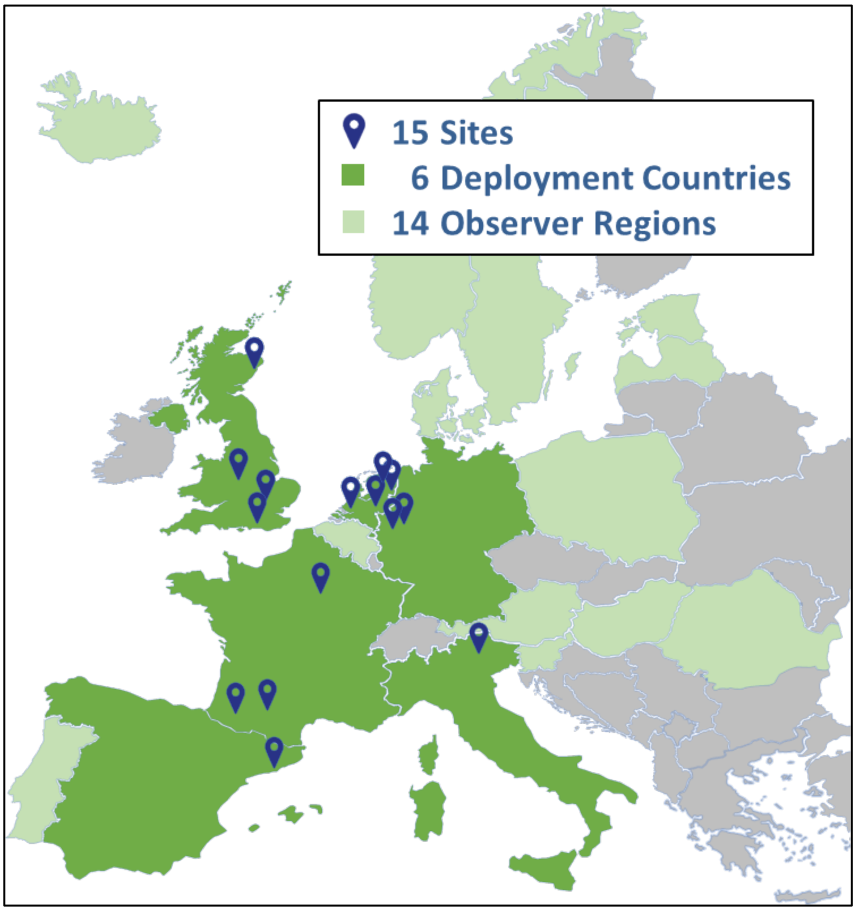


**Figure 0-1: The deployment sites and observer regions in JIVE and JIVE 2.**
The sites are Aberdeen, Auxerre, Barcelona, Birmingham, Bolzano, Brighton, Emmen, Gelderland, Groningen, the Cologne region, London, Pau, South Holland, Toulouse and Wuppertal. The local fleets range from 5 to 54 FCBs, typically 10 to 20. As of May 2024.

In any project there is nearly always more than one way to undertake the various tasks, and some are more likely to be successful than others. There are also lessons to be learned from actions that work, as well as actions that were not successful. The monitoring and analysis activities of JIVE and JIVE 2 include capturing challenges and Best Practice solutions on the path to the commercialisation of FCBs.

To assist readers to focus on particular areas of the projects, the information provided has been broken down into Stages and sub-stages. Project Stages have been described as in Figure 0-2. This report is structured accordingly. While these are documented as a sequential process, in practice the process is commonly iterative and circular, with different stages being revisited as issues emerge and are resolved.

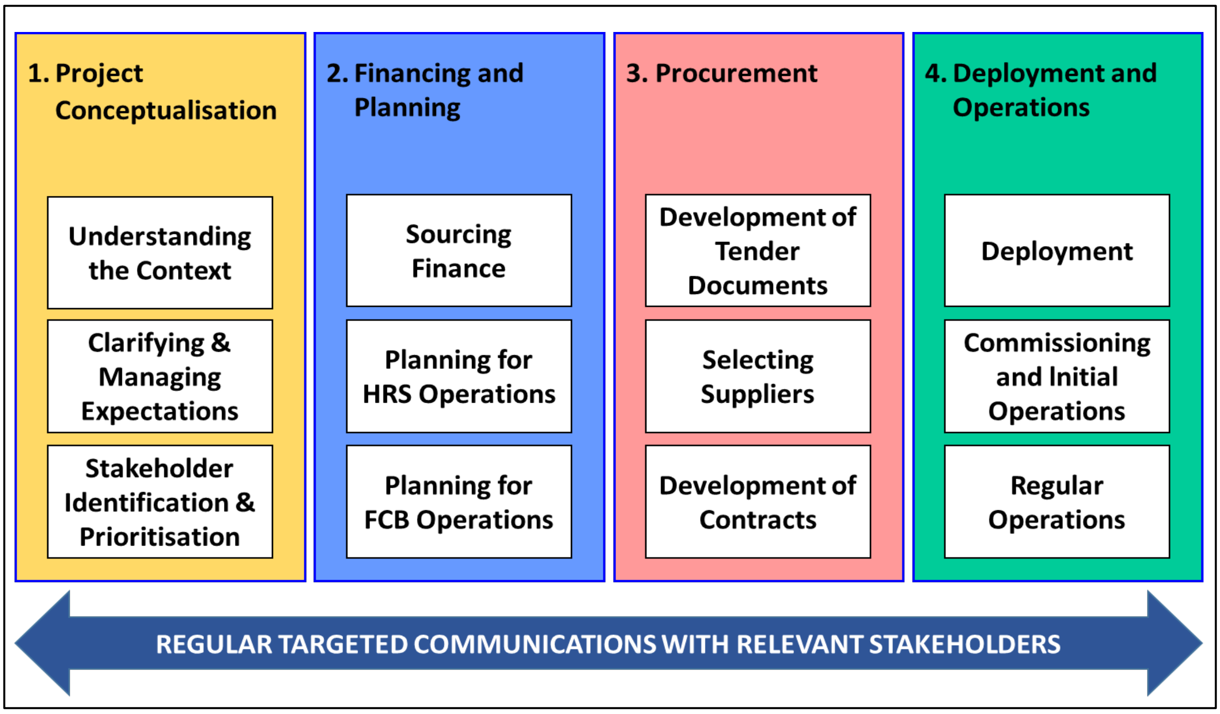


**Figure 0-2: Stages and sub-stages of a project to demonstrate FCBs and their hydrogen fuel infrastructure.**

The main purpose of this document is to bring the information from seven project years together into one place, so that it can readily be forwarded to external stakeholders. External stakeholders include decision makers from municipalities and regions, Public Transport Authorities (PTAs) and Public Transport Operators (PTOs) who may be considering adopting FCB technology. Some actors, such as policy makers, mainly require high level and strategic information. Others, the "hands-on" people at PTA/PTO level who have to deliver project outcomes, need more practical details. Detailed information can also be important for technology suppliers.

The Best Practice solutions documented here are those actions and approaches that have worked well. They are reported along with the challenges encountered that often prompted a need for a solution or different approach. It is important to note that some of these actions and approaches occurred and were successful because of the specific context they were in. This may include the specific local public transport arrangements and organisational responsibilities, local, regional or national political agendas, financial or environmental policies. This should be considered when reviewing and evaluating Best Practices for possible use in other contexts.

The challenges recorded are problems reported from the deployment sites that threatened the success and/or significantly delayed the local activities, often resulting from actions and policies that did not work as well as anticipated. The lessons from 'difficulties' encountered are often as important, arguably more important, than approaches that worked well from the start.

In addition to addressing the four project Stages, Section 5 of this report puts forward a number of "Issues to be Addressed to Support Future FCB Deployment" and, in some cases, suggestions are made on how to address these matters.

Some issues are discussed in more than one Stage or sub-stage. This replication frequently reflects the importance of the issue throughout the project, while in some instances it is due to the iterative and circular nature of project development as mentioned above. This also highlights that the Stages are interlinked significantly, and that certain topics must be addressed earlier on in order to prevent potentially disruptive setbacks at a later point in time.

Some of the information in this document dates as far back as 2018 but has survived successive updates (sometimes with revision) in 2022 and 2024. As such, and for the foreseeable future, it remains current. Note that this document has been made as concise as possible, focussing on key issues, rather than trying to cover every possible aspect or issue that may occur in the course of demonstrating FCBs.

The Best Practice report is not intended to be read in one sitting. It will be most beneficial if consulted for regular guidance as needed, in particular in the early phases of implementing FCBs and HRSs. A stage by stage, disaggregated form of the report will be made available at: https://fuelcellbuses.eu/category/starting-your-fcb-project under the Start to Implement side bar.

This final Best Practice Report 2024 has a somewhat different structure than the previous releases. The Case Study (formerly Section 5) replaces the executive summary at the very beginning of the document in order to provide a more 'readable' and less duplicative summary Section. Items that were previously found in this Section 0 have been relocated into 0 (on the JIVE and JIVE 2 projects) and Annex B (on the information gathering and processing method). Section 4 (Deployment and Operations) has been comprehensively expanded, while Section 1 to 3 have undergone limited adjustment and refinements, as mentioned. The 2018 survey of expectations at the deployment sites had been revisited as to whether expectations have been met and regarding the level of satisfaction with bus and refuelling infrastructure performance, see Annex C.

# 1 Stage 1: Project Conceptualisation

## 1.0 Introduction

Developing the overall concept of a FCB project sets the scope and, in many ways, the basis for the overall success of the project. The Project Conceptualisation Stage provides the context within which the buses will operate and be perceived by the key stakeholders.

Paying attention to the overall vision can also encourage a broader framework within which other applications of hydrogen ($H_2$) and fuel cell (FC) technology can be developed and utilised. These can provide a means to address energy system wide and environmental issues as well.

A key factor in this and all subsequent Stages is deciding which organisation will be the lead partner, its roles, responsibilities and accountabilities, and those of other key partners in the project. Commonly the lead partner is either the PTA or the PTO.

In general terms, the PTA is the organisation within the local or regional public administration that has the legal responsibility for making sure that there is a public transport system, its general terms and conditions, and arranging the contracts with operators. The PTO is the organisation, frequently but not always a private company, that operates the public transport service, in this case, the FCBs and their routes. There are many variations to these general arrangements and relationships. For example, bus ownership might be with the PTA or PTO, the PTO might be an independent company or owned by the local administration, the PTO may maintain the buses or contract that out to another organisation.

This project Stage has been considered in three sub-stages:

- **Understanding the Context** – why does a city or region decide to participate in a FCB project and what links can such a project have to other plans and activities of the city or region (Section 1.1)
- **Clarifying and Managing Expectations** – understanding what expectations the relevant stakeholders may have of the project outcomes, and ensuring they are realistic (Section 1.2)
- **Stakeholder Identification and Support** – developing a Stakeholder Map (including prioritisation) and Communication Plan and implementing it early in, and continuously throughout the project (Section 1.3)

These sub-stages are likely to run in parallel and influence each other, rather than being addressed one by one.

## 1.1 Sub-Stage: Understanding the Context

JIVE and JIVE 2 local site coordinators were asked to provide the reasons for participating in the projects. Table 1-1 summarises the findings.

The site coordinators also provided insights into the major challenges encountered and solutions found in this initial project stage. Why had 'selling' the project been relatively smooth and easy, and what had been done do to make this happen? Why had problems emerged and what could have been done to avoid them? Table 1-2 summarises this feedback.

Table 1-3 gives an overview of useful resources when starting a FCB project. More details in terms of resources are presented in the following sections.

Overall, there are two aspects of developing a FCB project which can have considerable influence on the ease and success of the future project path. FCB projects which have been established:

- within a broader industry / energy system / environmental context,
- with realistic expectations which recognise that the technology is still developing (see next sub-stage),

are more likely to be, and be perceived to be, successful by immediate stakeholders and the broader community.

One of the site coordinators stressed the importance of periodically re-reading written resources (like this report). This approach gave them an ability to recognise important details and issues that had occurred in earlier projects and that tied in with issues arising during their own project that were not obvious when studying the documents at an earlier stage. In effect, they gained a better understanding of the extent of their knowledge gaps. Their project has progressed well.

**Table 1-1: Project Conceptualisation – Major reasons why the JIVE/JIVE 2 sites decided to start a FCB demonstration project.**
Based on 22 responses (Survey 2018, see Annex B). Six category options were provided, up to three could be selected; typically two or three were ticked.

<table>
<tr><th>What have been the major reasons for sites deciding to start a FCB project?</th><th>Number of respondents choosing this option</th><th>Comments</th></tr>
<tr><td>Looking for alternative fuel options</td><td>15</td><td rowspan="7">• FCB activities are being increasingly put into a broader context - such as part of a regional hydrogen strategy. This can also help facilitate support from a broader range of stakeholders not directly involved in the FCB project<br>• National and local emission and clean energy requirements are playing an important role<br>• The future ambition / next step is 50+ buses per site and whole depots moved over to FCBs<br><br>Note: As of 2024, there are sites where more than 50 buses are being deployed</td></tr>
<tr><td>City/Region wants cleaner air</td><td>13</td></tr>
<tr><td>City/Region committed to combatting climate change</td><td>11</td></tr>
<tr><td>Funds available from sources outside city for bus projects</td><td>11</td></tr>
<tr><td>Part of local environmental programme</td><td>10</td></tr>
<tr><td>Bus manufacturer made an offer</td><td>1</td></tr>
<tr><td colspan="2">Other reasons and objectives mentioned by the respondents include:<br>• Ambition to be in the forefront in innovation generally, and public transport in particular<br>• PTO/PTA wants to showcase emission-free transport<br>• Regional policy on zero emission public transport: From 2025 only emission-free buses to be ordered<br>• Part of regional hydrogen strategy / Part of an industry strategy<br>• To use hydrogen for storage of wind energy<br>• Part of overall transition to renewable energy in the region</td></tr>
</table>

**Table 1-2: Project Conceptualisation – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Starting with an innovative project**<br>• Hydrogen is a relatively new fuel in public transport, and its introduction poses challenges very similar to other innovative projects<br>• While there is nothing exceptional in terms of project management when setting up and running a FCB project, such highly innovative activities require considerable resources. Many respondents mentioned that, in addition to finance issues, they did not have enough people and time for the project | **Build a vision**<br>• Communicate how your FCB project links to/supports a vision which includes local or national industries, community use for hydrogen and/or clean energy supply in general; this may have to start with very basic facts, such as battery electric buses (BEBs) being not the only zero-emission option and why FCBs can better fulfil local needs<br>• Know and connect with the political agenda for low carbon vehicles at any or all of local, regional or national levels<br><br>**People make hydrogen happen**<br>You will need:<br>• A committed Project Team consisting of knowledgeable and experienced staff<br>• Effective, collaborative team work to develop the project and overcome challenges<br>• Committed and well-informed organisational decision makers and elected officials |
| **Political/Legal environment can intervene**<br>• The political/legal environment can adversely affect the project e.g. elected supporters can lose an election; complying with national laws can delay action | **Know your context**<br>• Avoid or mitigate against getting caught up in election cycles<br>• Understand legal frameworks for tendering, contracting, safety permitting |
| **Preparatory work can be extensive**<br>• Innovative projects mean a lot of information needs to be gathered and there are not a lot of templates available to follow<br>• A key challenge is to understand and accept that there will be things you are unaware that you don't know, and that you cannot absorb and understand every piece of information when you, for example, read recommendations from an earlier project for the first time | **FCBs and HRSs**<br>• Find out as much as you can about FCBs and HRSs early in your project conceptualisation; re-visit resources regularly as questions arise<br>• Be clear on the benefits of FCBs – but be equally honest about the costs and risks<br>• Visit city sites where FCBs are in operation to obtain first-hand information<br>• Attend workshops offered by ongoing projects to learn about experiences, challenges and solutions<br>• Try to obtain written information in local language to forward to your stakeholders |

**Table 1-3: Project Conceptualisation – Useful Resources.**

| General | Setting up a FCB Project | Information to assist Communications |
|---|---|---|
| • Knowledge of local/regional/national zero and low emission vehicle policies. For example:<br>➢ The "Clean Vehicles Directive" on the promotion of clean and energy-efficient road transport vehicles has recently been revised. It impacts on the procurement strategies of PTAs/PTOs: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0033 Also consult information on how the Directive has been implemented in your country<br>• Basic properties of hydrogen including comparisons with other energy carriers/fuels: http://www.h2data.de/<br>• Dedicated resources for Funding, Planning and Procurement can be found in corresponding tables in the following sections. | • Visiting and talking to experienced cities in your country/elsewhere in the EU<br>• Knowledge Briefs in 9 European languages: https://www.uitp.org/publications/fuel-cell-buses-best-practices-and-commercialisation-approaches/ *(current versions from mid-2020, updates planned for mid-2024)*<br>• A Guide to Fuel Cell Bus Deployment can be found on https://fuelcellbuses.eu/category/starting-your-fcb-project<br>• Reports from JIVE, JIVE 2 and other projects are available here: https://fuelcellbuses.eu/publications<br>• Reports from the NewBusFuel project on large scale HRSs, including a Guidance Document: https://fuelcellbuses.eu/public-transport-hydrogen/new-bus-refuelling-european-hydrogen-bus-depots-guidance-document-large | • Reports from the CHIC project at https://fuelcellbuses.eu/projects/chic including:<br>➢ Influencing factors to the acceptance of fuel cell and hydrogen technologies in public transport (focussing on bus drivers, stakeholders and the general public)<br>➢ Extract from the above report with key learnings |

## 1.2 Sub-Stage: Clarifying and Managing Expectations

Local JIVE and JIVE 2 coordinators were asked their initial expectations for the major project outcomes. Table 1-4 presents the findings. These expectations and the reasons for starting a FCB project (Table 1-1) constitute important elements of the narrative ('story') to be communicated to stakeholders. The focus of the communication, and the level of detail depends on the individual stakeholder group (see Section 1.3).

Expectations were also collected, in 2018, on quantitative targets e.g. expected availability of the FCBs and HRSs, fuel consumption, time required to refuel a bus. In summary, site coordinators had high project expectations. They sometimes exceeded the targets defined in the project proposals. These initial expectations were re-visited in 2023 in order to compare the early findings with what the perceptions of the actual experience have been as the end of the projects approaches. In the 2023 perceptions survey a distinction was made between achievement and satisfaction. Details can be found in Annex C.

In the preceding project CHIC (2010 – 2016) expectations were also high. When, towards the middle of the demonstration phase, buses or stations did not always perform as anticipated, this led to disappointment and put local players under pressure from their supervisors, funders or the public. It also led to some problematic relationships between some of the demonstration sites and their FCB or HRS suppliers.

Setting up a FCB project today still requires the strong support of many stakeholders to provide personnel capacity and relevant expertise, funding etc. Acquiring this support can also bring the risk of 'overselling' the technology and raising very high expectations. On the other hand, high initial expectations may be necessary to get such a project approved at all. These expectations must be well managed during the project. For example, stakeholders must be prepared for challenges, have them explained when they occur, and feel comfortable that solutions will be found.

Interviews carried out in the acceptance study of the CHIC project showed that a perceived lack of communication led to irritations and scepticism, and, at worst, loss of support. The study concludes that whenever there is a lack of official information, there is a risk of unofficial stories emerging, made up and communicated by people looking for a story or wanting to influence the process (see report "Factors influencing the acceptance of fuel cell and hydrogen technologies ...", Table 1-3).

**Table 1-4: Project Conceptualisation – Major Outcomes Expected by the Deployment Sites.** Based on 22 responses (Survey 2018). Six options provided, one or more options could be selected.

| Expected major outcomes of the local FCB Projects | Number of respondents choosing this option | Comments |
|---|---|---|
| Refuelling technology highly reliable and maintenance free | 14 | • While the bus prices and operating costs were a concern (see Section 2), most respondents anticipated that an acceptable (low) level of cost will be achieved in the future<br>• While fossil fuel technology was not considered to have a future in 2018, less than half the respondents seemed to expect a commitment to FCB technology at scale in the short-term. This uncertainty is no doubt common among early stages of adoption of new and disruptive technology |
| Clear idea of future public transport bus technology | 13 | |
| Bus technology highly reliable and maintenance free | 12 | |
| Commit to a future FCB technology in short term | 8 | |
| FCB technology likely to be too high cost to be sustainable | 2 | |
| Likely continuance of purchasing fossil fuel technology into the future | 0 | |

## 1.3 Sub-Stage: Stakeholder Identification and Support

There is a wide range of stakeholders who can provide important and powerful support to your FCB project, or just as powerful opposition. On the support side, as an example, an influential and involved Steering Committee can provide very important political support. It might consist of senior representatives from the local administration and the PTA/PTO, as well as respected political leaders (political 'champions'), to maintain support and obtain advice. It may also extend to technology and/or renewable energy suppliers. On the opposition side, these may be very local, such as neighbours to the proposed refuelling site, or quite distant, such as national or international environmental organisations.

The relevant stakeholders need to be identified, their field of impact mapped, and a Communication Plan for engaging with them established and implemented. Not all stakeholders will have the same kind or level of potential impact or be relevant to every stage of your project.

Figure 1-1 shows a *sample* Stakeholder Map that distinguishes between project Stages. In addition to specific stakeholders, it includes other parties of key relevance, such as cities/sites with existing experience of FCB demonstration, and potential suppliers of HRSs and FCBs.

The task of working with the different stakeholders needs to be prioritised. For instance, when and how to engage with the media must be carefully thought out and how you communicate with influential decision makers must be appropriate.

The prioritisation can be done by mapping the stakeholders on a matrix with respect to concern and impact/importance, as exemplified in Figure 1-2.

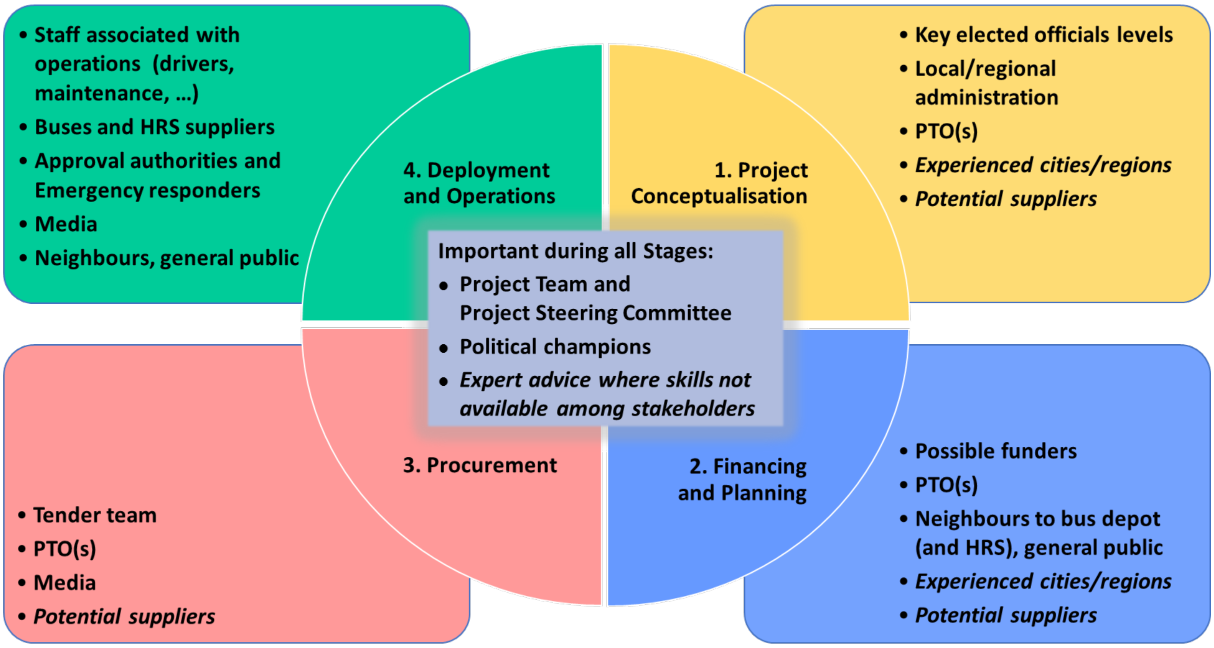


**Figure 1-1: Sample Map of important Stakeholders and (in italics) further parties of key relevance during the Stages of a FCB deployment project.**

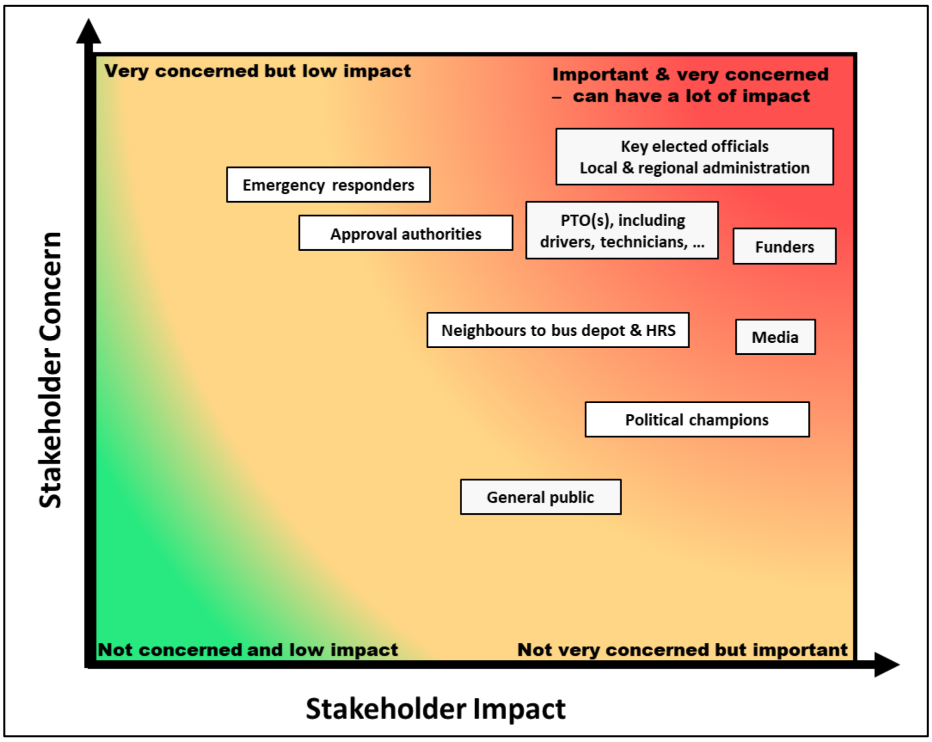


**Figure 1-2: Example of a Community Stakeholder Prioritisation Map.**

It is important to be aware that the criticality of the individual stakeholder groups varies from site to site and this is just a sample map for illustration. Note also that individual players can have different roles (and, therefore, different criticalities) at different times during a project. In particular, the fire brigades are part of the Emergency Response but usually also have a say when it comes to permitting of the HRS and the FCB maintenance workshop. [*Chart based on "People, Transport and Hydrogen Fuel, Guidelines for Local Community Engagement when Implementing Hydrogen Powered Transport" which can be found at* https://fuelcellbuses.eu/public-transport-hydrogen/people-transport-and-hydrogen-fuel-guidelines-local-community-engagement]

While this attention to stakeholder engagement may appear obvious, it is often overlooked under the pressure of other more immediate tasks. One essential element of this activity is the requirement to keep in contact with the stakeholder through active, customised engagement. Passive communication such as Newsletters, Press Releases and Social Media updates are useful communication channels but cannot replace face to face discussions with key stakeholders. Personal communication of project status and listening to concerns and issues are very important in heading off possible obstacles, and potentially re-shaping project elements to address questions that have been raised.

Planning to maximise the leverage that can be gained once your FCBs are operating is also important. Experience has shown that some of the best ambassadors for the new technology are bus drivers who thoroughly enjoy the opportunity to be part of an innovative programme. They are also the people who have the most contact with the general community. This is an important insight for on-going broad dissemination and communication.

Overall, the importance of active, targeted communication carried out throughout the project cannot be overstated. Experienced project sites note this again and again.

# 2 Stage 2: Financing and Planning

## 2.0 Introduction

As can be seen from the Stages chart (Figure 0-2), following Conceptualisation of the project, the next task is to find ways to meet the costs of the project and commence planning. As of the time of writing, the additional costs of FCBs over and above the costs of buying and operating conventional diesel or natural gas buses still can only be met by grant funds of some sort. One of the goals of FCB demonstration at scale in JIVE/JIVE 2 has been to reduce these additional costs and advance the shift from grant funds for projects to normal (i.e. commercial) bus fleet finance arrangements.

## 2.1 Sub-stage: Sourcing Finance

Getting the money for any innovative initiative can be complex and difficult. This is especially so when the initiative is being developed and implemented within a commercial public transport bus operating environment. While money to buy (capital expenditure; CAPEX) and operate (operating expenditure; OPEX) conventional buses is clearly available, additional CAPEX and OPEX associated with the project (for purchase, training, maintenance and other operating costs) will need to be met to fully cover the increased Total Cost of Ownership (TCO). For the PTOs to feel comfortable participating, this extra investment risk needs to be guaranteed by additional funds. Note however, that this will require establishing clarity on the ownership of the FCBs so that costs are correctly allocated.

The major source of this additional money in JIVE and JIVE 2 has been the Clean Hydrogen Partnership that co-funds research and innovation activities. Funds from the Connecting Europe Facility (CEF), which supports infrastructure investment, through the MEHRLIN project (Models for Economic Hydrogen Refuelling Infrastructure) have supported the HRS implementation at several JIVE/JIVE 2 deployment sites. Various levels of local, regional and national government have also contributed. In some cases, such as in the UK, funding from low emission vehicle and government innovation initiatives has been provided. Some funding, such as for the Groningen project in The Netherlands, has also come as one element of a much broader, energy system or economy wide vision for hydrogen and fuel cells. More recently, funding from private sources has also emerged in some countries. Organisations with new business models are offering "all-in" packaged solutions. Leasing arrangements are also being utilised in newer FCB projects. Finally, while immature, industry may work flexibly with purchasers to help them achieve their goal (see Table 2-7 for links to a sample list of suppliers).

Complicating the process of raising external funding is also the fact that establishing the additional costs that are expected to arise from a FCB project is quite complex at present. Some of these costs may well arise after the end date of the co-funded phase ('beyond project' costs), resulting from the potential for ongoing use of the FCBs and HRS up to the end-of-life of the buses. Nonetheless, being able to present reliable cost figures is essential to gain support from stakeholders and for applying for financial support from whatever source. Table 2-1 and Table 2-2 summarise the challenges encountered, and Best Practice solutions found, with respect to expenditure and funding. Table 2-3 provides useful information for sourcing finance.

Overall, sourcing funds in addition to the Clean Hydrogen Partnership funding has not been easy. No site has found this trouble free, including those that with experience from previous projects. However, there were no patterns that could be identified that could lead to success or problems. Much seemed to depend on specific knowledge of local, regional and national funding programmes, and local circumstances at the time, particularly political circumstances[1].

Possibly the only common driver for funding is the existence of supra-national (EU) and national targets for emission reduction. These have clearly acted to galvanise action from those involved in the provision of public transport. The pressure in this respect has increased via the revised Clean Vehicles Directive (CVD) that sets out mandatory minimum procurement targets for clean light-duty vehicles, trucks and buses for 2025 and 2030, including zero emission buses.

A challenge for the nearer future will be to move from co-funding models to commercial financing models.

Beyond TCO, it is very beneficial to undertake Life-Cycle Costing (LCC). This considers, (in addition to TCO) costs resulting from the consequences of emitting greenhouse gases (GHG) and other pollutants. These are largely the costs associated with health treatment and climate change impacts as well as mitigation and adaptation policies. The savings achieved by replacing conventional buses with zero emission alternatives can be a useful argument when negotiating for additional funds or, in the future, cheaper loans from government for whom these costs are a large budget item.

[1] The Clean Hydrogen Partnership will not fund pure FCB demonstration projects in the future. However, buses and their infrastructure can be co-founded as part of their call for proposals for "Hydrogen Valley" projects with a more comprehensive approach, meant to initiate integrated hydrogen ecosystems. Other options for obtaining financial support for the purchase of vehicles are in place, see Table 2-3.

The energy crisis in Europe that commenced in the early 2020s also led to increased hydrogen prices at several sites. That highlights that business cases and funding need to be robust, and that price clauses in supply contracts must be well understood.

**Table 2-1: Sourcing Finance – Determining the costs.**

| Challenges | Best Practice Solutions |
|---|---|
| **Level and Complexity of Costing:**<br>• Uncertainties around pricing of FCBs, HRSs, and $H_2$ fuel<br>• Demand for FCBs is still higher than supply, so the industry competition is immature<br>• Inexperience with costing CAPEX and calculating revenue in short term (demonstration) projects<br>• Inexperience and complexities of costing OPEX<br>• Costing uncertainty is compounded by multiple options for $H_2$ fuel supply<br>**Lack of Information:**<br>• Not enough general experience to be confident about bus performance in operations<br>• Lack of financial models | • Build a draft but comprehensive business case from day one, then refine it as your project progresses, thereby improving accuracy. The business case must include the refuelling infrastructure if this is not covered by another responsible body<br>• Learn from other cities with experience; some will be willing to provide sample specification information and provide figures from their operations<br>**CAPEX:**<br>• Consider procuring jointly with other sites to get better prices through higher volume (see Section 3), for the FCBs and for the HRS and $H_2$ fuel supply or alternatively for 'hydrogen as a service'. This can work, provided the sites have similar requirements and specifications, and similar regulatory structures<br>• Consider including preventative maintenance costs in the capital costs of the buses to reduce the operating costs, which are a key consideration for any operator<br>**OPEX:**<br>• $H_2$ pricing can be difficult. A lower price can be achieved if a minimum purchase quantity is guaranteed to the supplier ('take or pay') and the contract is lengthy and offers break clauses (ability to stop the contract at defined points)<br>• Seek to obtain renewable ('Green') $H_2$, but be aware that sources currently can be limited (for information on $H_2$ supply and on the EU definition on Green $H_2$ see Table 2-7 and Section 3 on Procurement)<br>• Indicative bus performance in terms of efficiency and maintenance costs are available through the JIVE projects<br>**TCO**<br>• Be thorough with TCO, including 'beyond project' costs after the co-funded phase. This includes being clear which technology you are looking to compete with from the outset (diesel/diesel hybrid/battery electric). In the past PTOs have looked for parity with diesel, now however BEBs are the competitor in terms zero emission propulsion.<br>• Be sure to include the requirements of maintenance, training and certification for a new technology<br>• Be sure to include the residual value of the buses and the HRS |

**Table 2-2: Sourcing Finance – Covering the costs.**

| Challenges | Best Practice Solutions |
|---|---|
| **Knowledge of Funding Sources and Interaction with Funders:**<br>• Knowing and connecting possible funding sources<br>• Convincing funders<br>• Timeliness<br>• Making sure that interactions between different sources of funding do not interfere with each other<br>• Weaving purchase of new buses into routine fleet investment<br><br>**Politics:**<br>• Changes in/uncertainty regarding the political situation/agenda.<br>• Competition from other zero emission buses (BEBs). | • Research funding sources well and ensure their criteria (goals/timelines/limits) align with your project; read the terms and conditions of grant funding thoroughly and seek legal support to do so<br>• Sources generally include a component of investment from the PTO or the PTA allocated to normal purchases; useful additional sources are government (all levels) low/zero emission and energy programmes<br>• Connect with funders informally or find good intermediaries or experts<br>• Present a thorough business case to show that you are serious about your project (see Table 2-3)<br>• Service funders well; never assume reliable, lasting commitment<br>• Consider working with another site to jointly seek funds, or co-locate with industrial 'anchor demand' for $H_2$ supply to increase volume and therefore lower price<br>• Consider employing experts to seek and prepare funding proposals<br>• Be aware there may be issues that arise:<br>➢ from providing subsidies to private organisations (e.g. PTOs)<br>➢ about the ownership of assets purchased with funder input and<br>➢ in trying to coordinate with the investment cycle of PTOs<br>• Try to separate funding sources into separate sub-projects but also try to avoid feeding funds from different sources into the one item (e.g. source 1 = FCBs, source 2 = HRS, rather than sources 1 and 2 = FCBs, sources 3 and 4 = HRS)<br>• Consider LCC to estimate the avoided external costs via savings of emissions of GHG, NOx and particulate matter and strengthen your case; there is information available to help quantify external costs (see Table 2-3) |

**Table 2-3: Sourcing Finance – Useful Resources.**

| Resources | Where to find the Resources |
|---|---|
| **Building the Business Case** | • JIVE 2 2023 TCO Report "Comparison of fuel cell with battery electric bus systems against operational, economic and environmental parameters" combined with JIVE/JIVE 2 Report "Environmental Impacts and External Cost Benefits of Fuel Cell Hydrogen Bus Systems": https://fuelcellbuses.eu/publications<br>• MEHRLIN project (Models for Economic Hydrogen Refuelling Infrastructure) 2023 Report "Analysis of economic data": https://fuelcellbuses.eu/publications<br>• Report "Business cases to support fuel cell bus commercialisation" (2017): https://cordis.europa.eu/project/id/671426/results/<br>This resource looks at the business case for FCBs as a whole but it will provide some insights for a PTO level. |
| **Knowledge of funding sources at European, National (including local / regional) levels**<br>*Note:* Resourcing can flow from having a political advocate. However, be aware of the impact of election cycles and the importance of regular communication with these champions | **European**<br>• The Clean Hydrogen Partnership publish regular calls for project proposals, such as for implementing "`Hydrogen Valleys" that fleets of FCBs can be part of: https://www.clean-hydrogen.europa.eu/apply-funding_en<br>• Innovation Fund for demonstration of innovative low-carbon technologies.: https://ec.europa.eu/clima/policies/innovation-fund_en<br>• Just Transition Fund: https://ec.europa.eu/regional_policy/de/funding/jtf/<br>• European Regional Development Fund: https://ec.europa.eu/regional_policy/en/funding/erdf/ https://ec.europa.eu/inea/en/connecting-europe-facility https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/apply-funding/blending-facility<br>• Other possible streams of funding include cross-border cooperation under the INTERREG programme with various regional activities, such as for the North Sea region: https://northsearegion.eu/, and further programmes under European Structural and Investment Funds umbrella: https://ec.europa.eu/regional_policy/en/funding/<br>• As purchasing moves from project funding to regular financing, support from the European Investment Bank (EIB) is expected to come into focus: https://www.eib.org/en/; national/local banks can be expected to follow<br>**National**<br>• Project funding provided by National Governments such as the German National Innovation Programme Hydrogen and Fuel Cell Technology (NIP): https://www.now-gmbh.de/ |

| | |
|---|---|
| | • General funding databanks, such as https://europa.eu/youreurope/business/finance-funding/getting-funding/eu-funding-programmes/index_en.htm |
| **Appeal to social, environmental and cost benefits of clean air/re-duced emissions** | **Calculating external costs avoided**<br>• JIVE/JIVE 2 2023 Report "Environmental Impacts and External Cost Benefits of Fuel Cell Hydrogen Bus Systems" combined with JIVE 2 Report "Comparison of fuel cell with battery electric bus systems against operational, eco-nomic and environmental parameters": https://fuelcellbuses.eu/publications<br>• Costs associated with the health impacts of transport emissions have been examined in some depth. As a starting point see: https://www.eea.europa.eu/signals/signals-2016/articles/transport-and-public-health<br>• "Sustainability Assessment of FCBs in Public Transport": http://www.mdpi.com/2071-1050/10/5/1480/pdf<br>• Total Cost and Revenues of Ownership - an innovative benchmark analysis: https://www.sustainable-bus.com/wp-content/uploads/2022/05/Bocconi-A-benchmark-analysis.pdf |

## 2.2 Sub-stages: Planning for HRS Operations and for FCB Operations

Clearly the operational stage is the most important aspect of a FCB project. It is the reason for embarking on the project and will provide critical information to determine the future of the application of $H_2$ and FCB technology at that site. It will also be the most public activity of the project and therefore most open to scrutiny. Success is critical and only careful and thorough planning can achieve this. The saying *"Failing to Plan is Planning to Fail"* certainly holds true when applied to a FCB Project.

While there are some Best Practices that are applicable to only the planning for the bus or the HRS operations, there are some general approaches and actions that are applicable to both. These are laid out in Table 2-4.

Planning Challenges and Best Practice Solutions related specifically to HRSs or to FCBs are set out in Table 2-5 and Table 2-6. It should be noted here, that many of these have been re-iterated in the Deployment and Operations Stage (Section 4). This is because some of these challenges related to planning only come into clear focus when operations are imminent. JIVE/JIVE 2 sites reported a lot of activity during Deployment to address issues that might have been planned for but had either slipped out of focus or could only be implemented at the immediate pre-operations stage.

Some of the most useful resources for planning for operations can be found in Table 2-7.

Annex C summarises quantitative expectations for FCB and HRS performance as expressed by the sites at the beginning of the JIVE and JIVE 2 projects as well as the findings from a review of expectations five years later (as explained in Section 1.2).

**Table 2-4: Planning for Operations – General Best Practice Solutions.**

| | **Best Practice Solutions** |
|---|---|
| 1 | Visit/talk to experienced sites:<br>This strategy is perhaps the most helpful for all stages of developing and implementing a project. It can help give an early understanding of the complexity of issues and for 'just in time' advice at a later date |
| 2 | Align the timing of delivery and commissioning of HRS and buses:<br>Buses need to refuel during their commissioning phase |
| 3 | Plan for slow progress:<br>Hurdles and delays are common when introducing innovations – prepare all stakeholders for this and think in terms of Plan Bs as much as possible. Allow for the possibility of significant delay in timescales. Sites in JIVE/JIVE 2 have encountered up to 18 months delay. While this should not happen to this extent in the future, be prepared |

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| 4 | Plan for clear and consistent communication:<br>While this may seem obvious, it is not attended to due to a perception of more urgent issues. Have a Communication Plan for stakeholders and be rigorous in following it (see Section 1.3 on this matter). Assign responsibility for making it happen |
| 5 | Have clear and specific responsibilities, boundaries and accountabilities, e.g.:<br>• A PTO may not be the best to procure a HRS, but they know a lot about buses |
| 6 | Resource the planning stage well (people and time):<br>Thorough planning = smooth(er) procurement; expert assistance can be of help |
| 7 | Plan to set up a broadly-based tender team:<br>Tender teams need to have a wide range of expertise: apart from at least one member experienced with conventional tendering, this includes understanding of the technology (FCBs/HRSs), financial issues, risk management, contracting and legal frameworks (more on this in Section 3) |
| 8 | Engage early, often and widely:<br>Political advocates, city administration; local authorities (including firefighters etc.); in particular:<br>• PTO(s): These have a pivotal role in in ensuring the success of the introduction of this new technology. Brief all levels within the PTO(s) from CEO level to bus drivers with the appropriate information; a new fuel and new technology need thorough introduction.<br>• Talk to FCB and HRS suppliers: Get as much understanding of the technology as possible (see also Table 2-5 and Table 2-6) |
| 9 | Permitting:<br>Permitting is a time consuming issue in the context of planning and deployment; difficult to know how long this will take – not just because of delayed granting of permission but the fact that many regulators (authorities) do not yet have the required expertise; Best Practice has been to 'Educate your Regulator' i.e. have unofficial discussions with the authorities before handing in applications for permits, introducing them to the field and to what has been successfully deployed at other sites, presenting the plans/solutions, never asking them "What should I do?"; be willing to compromise on technical details |
| 10 | Data from FCBs and HRS:<br>The JIVE projects have shown that the performance data needed for seamless integration of both the FCBs and the HRS into the regular IT system (and often for co-funding institutions) are not always considered by the supplier. The data requirements need to be clarified early and be part of the planning process and questioning of suppliers |
| 11 | Be open to reason as everyone is still learning |

**Table 2-5: Planning for HRS Operations – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| • Risk: Determining risk sharing among the local partners can be difficult because you need to specify the equipment and its capabilities to know the risk, and you need to know risk to specify<br>• Determining Size: Optimising size (not too big not too small); forecasting size of hydrogen storage required now, **and in the future,** as well as planning for seasonal fluctuations in usage can lead to specifying unnecessary capacity resulting in additional cost; suppliers may offer equipment with 'locked specifications', so no scale up is available later<br>• Design and Location of HRS: Identifying the right location that meets the operator requirements; siting determines the HRS planning and HRS and FCB operational constraints and costs<br>• Numbers and Complexity of Decisions: Most PTOs and PTAs lack experience with HRS hardware and $H_2$ fuel supply, especially with location /permitting/regulations issues; setting HRS supply contract terms and conditions is complex; technical planning can be affected by changing national regulations<br>• Problems with Hydrogen Supply and/or Hydrogen Refuelling: Regular hydrogen supply from a local or external source can fail or be delayed, on-site hydrogen generation and/or the HRS can break down – see Section 4.1 and Table 4-3 for details and backup solutions | • Specify for Local Needs: As part of the dialogue among local stakeholders, review and refresh local needs such as HRS ideal location(s); HRS too far from bus depots will affect time to refuel (filling process plus travel time); however, be aware that a HRS requires a considerable area of a bus depot if that is where it is to be located; work out supply chains for $H_2$, including backup supply (numerous sites have mentioned that at the Operations Stage this has been essential to smooth operations; see Section 4)<br>• Inform yourself of the Legal Framework in which the HRS will operate, certification and permit requirements for the new technology and fuel; be prepared for lack of knowledge among regulators (see point 9, Table 2-4)<br>• Be familiar with emerging standards and guidance documents (see Table 2-7)<br>• Use Pre-Tender Processes such as Requests for Information; the limited and non-standardised market means that you will not be overwhelmed with information, but early necessary decisions will become clearer; try to get technical concepts from more than one potential supplier in the pre-tender stage.<br>• $H_2$ Supply: All $H_2$ supplied must be renewable ('Green') to fully address climate issues in particular; detailed rules on the EU definition of renewable $H_2$ were published in June 2023 (see Table 2-7); certification of renewable hydrogen may be required while that market seems to be in an emerging stage (see Table 3-3); in the short term renewable hydrogen supply may be difficult; consider all supply pathways offered there are quite a few available that may be adaptable to your context; encourage the industry to provide the solution i.e. make it an industry problem not an operator problem; make sure you understand the pros and cons of on-site and off-site production of the hydrogen<br>• Make early Decisions: Define 'must haves' to guide decisions; decide on scale; know permitting requirements; develop strategies to address TCO (price of the $H_2$ can be pivotal here); note any imperatives for location and design |

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| | • Options: Consider turnkey suppliers to buy a HRS from OR simply tender for a $H_2$ per kg price at the nozzle with the HRS built and operated by a contractor; there are also leasing models emerging which give the PTO full use of an HRS for a number of years, including maintenance and possibly the option to increase capacity over time. Involve an Expert who supports you with their experience and know-how<br>• Plan for the Future: Scalability and flexibility of the HRS is important for growing fleets and, possibly, for joint use with other vehicles |

**Table 2-6: Planning for FCB Operations – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| • Achieving PTO Buy-In: Some PTOs have concerns about becoming involved because of operational and maintenance costs and safety; training requirements; technical performance of $H_2$ technology<br>• Modifying Existing Depots / Routes: FCBs may need more space in depots; determining routes – not all routes may be suitable due to increased vehicle height/equipment on the roof; different or additional maintenance equipment and skills will be needed<br>• Operation and Maintenance for the Long Term: Ensuring the bus maintenance requirements are adequately met; ensuring the existing or new bus contract is competitive and can be maintained over the course of 10 -15 years<br>• Predicting Availability of Vehicles to ensure route service reliability is maintained - this could be a major issue when zero emission only bus zones come into effect and it is not possible to replace these buses with diesels | • Develop indicative Costing and Opportunities to De-Risk for PTOs: Calculate TCO and consider de-risking options (financial and other support) for engaging with commercial PTOs (Section 2.1)<br>• Develop good Partnerships: Involve the local stakeholders early & understand the impact of the new technology on them; engage the FCB supplier through Request for Information (RFI); engage with those who will work on the buses such as drivers and maintenance people and ensure that all are committed to exploring a new technology and making it successful<br>• Become familiar with Local Needs: Review and refresh local needs – routes, depot location; supply chain requirements; warranties and repair arrangements; understand the issues<br>• Awareness Raising and Training: Plan for this considering bus drivers & maintenance technicians, first responders, bus users etc. (see Table 4-5)<br>• Supply Chain: Plan for an efficient and timely supply of parts; ensure that the FCB manufacturer's supply chain is robust, and the suppliers have clear and firm obligations on warranties and repairs<br>• Maintenance: Consider carrying out all or part of the maintenance in-house - this will help you understand the technology more rapidly (see also Table 4-8 on bus maintenance procedures) |

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| | • Insurance: Engage early with insurers as few have experience of FCBs<br>• Plan for the Future: Consider scalability of solutions to enable options for the future |

**Table 2-7: Planning for Operations – Useful Resources.**

| Resources | Where to find the Resources |
|---|---|
| Talking to FCB and HRS suppliers and question them on their product specifications and experiences | For lists of suppliers see: https://fuelcellbuses.eu/suppliers<br>or search the membership list of: https://www.hydrogeneurope.eu/directory/industry<br>(Note that these lists provide an example only and may not include new/innovative new players.)<br>If possible, visit their factory and use your performance criteria to question them on performance |
| Talking to and/or visiting sites with operating FCBs and HRSs | For JIVE/JIVE 2 sites see Figure 0-1 or:<br>https://www.fuelcellbuses.eu/projects/jive and https://www.fuelcellbuses.eu/projects/jive-2<br>The authors of this report can provide personal introductions, see their e-mail addresses on page 2 |
| Reports from JIVE & JIVE 2 and from other ongoing and from completed projects | On https://fuelcellbuses.eu/category/starting-your-fcb-project:<br>• JIVE and JIVE 2 Best Practice (this) Report (2024): To be disaggregated for easy access Under 'Start to Implement' sidebar<br>On https://fuelcellbuses.eu/publications for example:<br>• Operator's Guide to Fuel Cell Bus Deployment (JIVE/JIVE 2)<br>On https://fuelcellbuses.eu/publications for example:<br>• Guidance for HRS consenting phase (JIVE 2)<br>• Public summary of the Final Report of the CHIC project (2010 – 2016)<br>• Introduction to fuel cell buses: Guidelines for operators (in German) |
| Particular reports on planning for HRSs | On https://fuelcellbuses.eu/publications for example:<br>• Info pack about the hydrogen infrastructure in Pau/France (JIVE 2)<br>• Recommendations for hydrogen infrastructure in subsequent projects (CHIC)<br>On https://cordis.europa.eu/project/id/671426/results/ for example: |

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| | • Guidance document on large scale hydrogen bus refuelling (NewBusFuel project)<br>• Review of regulations codes and standards with respect to hydrogen bus scale fuelling (NewBusFuel project) |
| Emerging standards for HRSs and supporting documents | On https://www.iso.org/standard/71940.html:<br>• ISO 19880-1:2020 "Gaseous hydrogen Fuelling stations Part 1: General requirements"<br>On https://cleanenergypartnership.de/en/approved-acceptance-procedure-for-fuelling-stations:<br>• Approved acceptance procedure for fuelling stations by the Clean Energy Partnership (CEP) / Safe Refuelling, including a CEP Guideline for ISO 19880-1<br>On https://cleanenergypartnership.de/en/refuelling-buses-and-trucks<br>• Information on the SAE J2601/5_202402 "High-Flow Prescriptive Fuelling Protocols for Gaseous Hydrogen Powered Medium and Heavy-Duty Vehicles", which currently has the status of "Technical Information Report", i.e. is not a standard yet<br>• Supporting information on refuelling protocols<br>On https://www.sae.org/standards/content/j2601/5_202402/<br>• High-Flow Prescriptive Fuelling Protocols for Gaseous Hydrogen Powered Medium and Heavy-Duty Vehicles J2601/5_202402 |
| Well-to-wheel emissions | A recent study (October 2021) can be found here:<br>https://www.zemo.org.uk/assets/reports/Zemo_Hydrogen_Vehicle_Well-to-Wheel_GHG_and_Energy_Study_2021.pdf |
| Definition of Renewable/Green Hydrogen | The underlying legislation of the definition of 'renewable hydrogen' in the EU is the Renewable Energy Directive:<br>• https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en<br>Two 'Delegated Acts' of June 2023 outline detailed rules on the EU definition of renewable hydrogen to ensure that hydrogen is produced from renewable energy sources and achieves 70% emissions savings. This is explained here:<br>• https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/renewable-hydrogen_en<br>The link above also provides access to the Delegated Acts: |

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| | • Delegated Act (EU) 2023/1184 on a methodology for renewable fuels of non-biological origin https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2023.157.01.0011.01.ENG&toc=OJ%3AL%3A2023%3A157%3ATOC<br>• Delegated Act (EU) 2023/1185 a minimum threshold for GHG emissions savings of recycled carbon fuels https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2023.157.01.0020.01.ENG&toc=OJ%3AL%3A2023%3A157%3ATOC<br><br>A summary of renewable as well as 'low carbon' hydrogen and supporting information can be obtained here:<br>• https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747085/EPRS_BRI(2023)747085_EN.pdf |

# 3 Stage 3: Procurement

## 3.0 Introduction

Procurement of the FCBs and HRS is the Stage that will determine the fundamental performance of the project. While the general steps and processes are well known, the procurement of FCBs and HRSs introduces some additional complexities. The technical details are likely to be new to the site and persons responsible for conducting this activity. For example, recognised standards for refuelling heavy duty vehicles (fills of >10 kg $H_2$) are still in progress (April 2024), so HRS performance can be difficult to assess.

An additional element that must be managed is the requirement for a close linkage between the FCB and HRS technology. The buses and the HRS must be compatible and be able to communicate to ensure quick and reliable refuelling (data flow is bus to HRS). For example, the type of $H_2$ tanks onboard the buses does have an impact on the design and performance of the HRS.

In the past, FCBs were equipped with Type III tanks, which are fibre-wrapped metal vessels. They do not require pre-cooling of the $H_2$ by the HRS unless the buses are refuelled very fast. Today, Type IV tanks are the choice of the most bus suppliers because they are lighter and cheaper. Type IV tanks are fibre-wrapped plastic vessels. Their lower thermal conductivity slows down the dissipation of heat which develops in the tank during the filling process. Overheating of the tank must be avoided for safety reasons. Keeping the tank temperature limit of 85°C can be ensured via a conservative (i.e. slow) refuelling process or by $H_2$ pre-cooling. Ambient temperature also impacts the process as higher air temperatures will increase the pre-cooling required.

It is also highly desirable that the timing of the arrival and commissioning of the FCBs and HRS are coordinated so that, ideally, neither one sits idle waiting for the other to be available. These factors have led some sites to procure both FCBs and HRS through a single process conducted by a single organisation such as the PTO.

Generally, however, while the PTO is likely to have considerable expertise in purchasing buses and be well placed to undertake this task for the FCBs, they are unlikely to have much, if any, expertise in HRS procurement. Accordingly, the PTO is likely to require external expertise for procuring the HRS, or this process should be led by a different party.

Some sites have circumvented this challenge (lack of experience with HRSs) by procuring ’$H_2$ refuelling as a service’, rather than buying and operating the actual refuelling hardware themselves. This puts the responsibility and accountability on the contractor to provide the required quantity and quality of $H_2$ and refuel the FCBs how, where and when required. One city site even put out a single tender for the complete system of buses, HRS and hydrogen fuel supply. This was successful, and other sites consider this as an option for the future.

Such solutions are also one way to address a request frequently made by both HRS and FCB suppliers that tender documents should focus on the performance outcomes required. In the case of the HRS, this could include the daily hydrogen demand, the length of the refuelling window and the maximum allowed time to fill per bus, while not stipulating technology details such as HRS storage size. This allows the suppliers to shape their tender solution in the most efficient and effective way, and at the best price. Tendering for performance outcomes, with appropriate penalties for not meeting these, is generally considered beneficial as it is keeping some flexibility in the specifications where possible.

It is important that issues of performance, warranty, maintenance and supply of parts (including timeframes for provision of service and precise responsibility) are clearly understood and agreed by all parties and well documented in the contracts. **Only what is documented will count after the contracts are signed**. Do not accept non-disclosure clauses that forbid you to talk to third parties when problems occur.

This Section is structured by initially documenting Challenges and Best Practice Solutions that are common to both HRS and FCB procurement (Table 3-1). Subsequently, technology specific issues relating to the Procurement of the HRS (Table 3-2) including $H_2$ fuel supply (Table 3-3) and Procurement of the FCBs (Table 3-4) are dealt with separately. Each of these processes is considered individually by the sub-stages of Developing of Tender Documents, Selecting Suppliers, and Development of Contracts in Table 3-2 and Table 3-4.

Sources of further information for this Stage are listed in Table 3-5.

**Table 3-1: Procurement of HRS and FCBs – Challenges and Best Practice Solutions applicable to both.**

| Challenges | Best Practice Solutions |
|---|---|
| Running separate but linked tenders for FCBs and HRS and timing them to come online together | PTOs know about buses; other players such as energy suppliers are more likely to know more about HRS equipment; PTA/PTO know about site works etc. Ensure procurement teams have cross over to keep timeframes, interfaces, responsibilities etc. consistent. |
| The market for both HRSs and FCBs is immature and delivery times can be unrealistic; availability can still vary greatly across different EU countries | • Do a market review: Determine which manufacturers are willing and able to deliver<br>• Very important to use manufacturers and experienced sites as sources of knowledge<br>• Always use a RFI to test the market, particularly where there are suppliers new to the FCB market |
| Finding a tender team that has the expertise to integrate FCB/HRS specifics in line with local tender and contract law | Take the time to gather a multi-skilled team and involve them early – legal / technical / finance – purchasing / energy / mobility; ensure that relevant stakeholders are engaged in aspects of evaluation and set up regular dialogue with them during the process |
| • Issues such as warranties and responsibility for maintenance and timely delivery of spare parts in a non-standardised supply chain (see also Table 4-8 and Table 4-11)<br>• Responsibilities of suppliers' third-party contractors add to complexities; unclear responsibilities for solving challenges that may arise can derail the installation of innovative systems | • Matters that are standard to diesel buses need to be made explicit with FCBs e.g. type and size of fuel tanks; intended refuelling regime (max. allowed time to fill etc.)<br>• Ensure that all parties involved on the supplier side are clear on who has ultimate responsibility and accountability for problems that may arise and that it is written into the contracts<br>• You may need an iterative process to contracts, particularly if many parties involved i.e. a cyclical process of refining the contracts<br>• **Detailed and clear contractual agreements will be paramount in resolving problems** |
| Ownership of equipment can be complex | Where there are multiple funders, ownership of the HRS and buses needs particular attention; ownerships arrangements can vary, e.g. one site arranged to become owners of the HRS after ten years when the $H_2$ supply contract with the HRS supplier ends, to ensure they could continue to get a competitive $H_2$ price |

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| Reliability and scalability cannot be assumed | Negotiate for scalability and specifically address reliability requirements for the FCBs/HRS – the most important factor for a public transport system (e.g. in the case of the HRS, the length of the windows during which the HRS will always be available) |
| • Maintaining communications with and between stakeholders throughout procurement process<br>• Significant training time is required for bus drivers/maintenance technicians/bus depot people | • Regular communications: Throughout the procurement process with and between the relevant stakeholders, in particular between the favoured suppliers and with the local authorities (including fire brigades and other first responders); funders should feel informed at all times<br>• Training by suppliers: Factor this into all procurement documentation |
| Safety assessments require attention (see also Table 4-10 on Safety in operations) | To address potential reservations by local authorities lacking experience, be proactive; consider resourcing an assessment for the HRS and the Bus Maintenance Facility; professional expertise can be very helpful to ensure compatibility and to smooth the permitting process |

## 3.1 Procurement of the HRS

As outlined above, the procurement of HRSs has generally been more difficult than acquiring the FCBs. This is partly due to the PTOs/PTAs having good communication networks with bus suppliers while mostly this is not yet the situation with HRS technology or suppliers. Therefore, careful consideration needs to be given about which entity is best placed to conduct HRS procurement.

Nevertheless, both procurement processes need to be closely coordinated from the perspective of technology and timing. Tender documents should include a requirement for the successful HRS and FCB suppliers to consult and collaborate on solutions in terms of interfaces and timing of commissioning. Table 3-2 summarises Challenges and Best Practice Solutions for the HRS side.

As also mentioned previously, there are alternatives to procuring and owning the HRS hardware. Some sites have tendered for supply of $H_2$ to the refuelling nozzle. That can be based on hydrogen generated locally or trucked in from remote production sites, but the responsibility for fuel supply and being able to refuel FCBs at any point in time as required will lie with a third party rather than with the PTO whose core business is bus operations. Table 3-3 lays out some of the issues that need to be considered in relation to $H_2$ supply. The advantages and disadvantages of these alternatives should be considered in the context of any long-term plans for FCBs, and possibly other fuel cell vehicles, in the region.

The reasons why there is a lack of standard HRS configurations for FCBs include:

- The small number of HRSs for buses/heavy duty vehicles so far, with many sites having special requirements related e.g. to limited footprint available,
- Lack of recognised standardisation documents (as explained above),
- Recently the uncertainties around the need for $H_2$ pre-cooling, and
- Differences in the type of $H_2$ supply (on-site generation, trucked in)

**Table 3-2: Procurement of HRS – Challenges and Best Practice Solutions.**

| **Challenges** | **Best Practice Solutions** |
|---|---|
| **1. Developing Tender Documents** | |
| • Specifying the HRS requirements so that the station meets vehicles' fuelling requirements, lack of HRS standardisation<br>• Determining capacity and redundancy needed<br>• Meeting innovative technology requirements; developing the evaluation criteria to match the requirements<br>• Permitting requirements<br>• Synchronising bus and HRS delivery.<br>• Implementation of HRS in bus depot with limited space and possibly coordinating with other new technologies (e.g. BEBs); allowing for flexible solutions<br>• $H_2$ pre-cooling requirements add to expense (CAPEX, OPEX); some sites have found that it can be avoided, at least with low ambient temperature and limited $H_2$ flow rates, while standardisation and an aligned approach of HRS suppliers is pending | • Write output-based technical specifications; consider the need for redundancy (e.g. two compressors in parallel to account for possible outages, pipes, dispensers) and fully understand implications of pre-cooling<br>• Set targets for technical outputs e.g. time to fill, but do not score or pay more for times that beat them; ensure contract includes data provision to monitor performance; refer to (emerging) standards like ISO 19880-1:2020 (see Table 2-7)<br>• Be clear on outcomes required and their consequences (revenue implications; warranties; maintenance) and have them confirmed by the potential suppliers<br>• Require a) at least one visit of potential suppliers to location for HRS (site specifics will affect proposal details) and b) agreement to work collaboratively with FCB supplier<br>• Choose correct tendering procedure: while large gas companies and smaller companies can both provide HRS, the latter may be more interested in submitting a proposal; experience is highly desirable<br>• Set target fuel price (combined fuel and maintenance) and set a price cap<br>• Consider whether to separate into two:<br>1. HRS hardware; 2. Fuel supply contract (see also following table) |
| **2. Selecting Supplier** | |
| • Manufacturers unresponsive; poorly written proposals<br>• Matching proposal specifications with tender specifications / technology offered not meeting expectations<br>• Deciding which supplier is best choice due to quite different concepts presented | • Invite quotes for standard and variant bids (to see what can be offered)<br>• Include 'innovative solutions' as one of the evaluation criteria – technical and commercial (e.g. scalability)<br>• Evaluate on TCO basis, including 'beyond project' costs |
| **3. Developing Contracts** | |
| • Negotiating the whole package to a commercially viable cost | • Be flexible with proposed solutions<br>• Clarify issues of ownership and responsibility (see Table 3-1) |

**Table 3-3: Procurement of $H_2$ Supply – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| <u>'Green' $H_2$ (situation pre-2023)</u>:<br>• A widely agreed definition of 'Green' $H_2$ is still not available<br>• 'Green washing' by providers is also still an issue.<br>• Funding bodies generally want Green $H_2$ | A definition of renewable/green $H_2$ for the EU is now in place, see Table 2-5 and Table 2-7.<br>To be sure that the hydrogen purchased meets the EU definition, certification may be needed. Some service providers offer such certification. The European Commission refer to 'Certification through voluntary schemes' and announce that they '… will remain in close contact with stakeholders and certification schemes to support the practical implementation of the framework and will also monitor its implementation. To this end, it is planned to launch a dedicated study in 2024:<br>• https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/renewable-hydrogen_en#certification-through-voluntary-schemes |
| <u>$H_2$ Price</u>:<br>Difficult to get a definitive price | • Set up fuel supply contracts for as long a term as possible (such as 10 or 15 years) to help encourage new investors and to improve price offered<br>• Price clauses in supply contracts must be well understood to avoid surprises in the case of an energy crisis, like in Europe in recent years<br>• It is possible to get a long-term contract at a better price if significant volume is assured. These contracts can contain break clauses (ability to stop the contract at defined points in the future)<br>• Co-locate with an industrial large-scale hydrogen consumer for better prices<br>• Set a target price and a price cap<br>• Evaluate on TCO basis, including 'beyond project' costs |
| <u>$H_2$ Purity</u>: Purchasing very pure $H_2$ required by fuel cell manufacturers can be difficult | High levels of purity are obtainable but at increased price; changes to the purity standards are being discussed but have not yet been implemented |
| <u>$H_2$ Metering</u>:<br>Measuring accurately enough the amount of $H_2$ refuelled (and supplied from external sources, if applicable), to meet weights and measures authorities' requirements, is still not a fully resolved issue for 350 bar refuelling | Ensure this issue is discussed with suppliers and understood by the local stakeholders |

## 3.2 Procurement of the FCBs

Procurement of FCBs, which is still more complex than procurement of diesel buses, has generally not been as difficult as procuring HRSs. Commonly the PTO, in agreement or collaboration with the PTA has conducted the FCB procurement. Tender documents should include a requirement for the successful HRS and FCB suppliers to consult and collaborate on the interfaces and timing of commissioning, as mentioned earlier.

As also mentioned above, most FCB manufacturers have emphasised that detailing performance outcomes in tender documents is preferable to detailing technology. They argue that this approach gives them optimum flexibility to shape their technology and tender proposals in the most cost effective and efficient way to meet the customer's needs. Specifying for outcomes is particularly pertinent when procuring FCBs. PTO personnel who are frequently involved in bus procurement may be tempted to insert their detailed technology experience and knowledge into tender documents. However, performance outcome requirements such as range, fuel economy, reliability and spare part replacement times have turned out to be more useful.

A cluster coordination initiative was supported by the Clean Hydrogen Partnership. This was designed to aggregate demand for FCBs and to develop approaches to Joint Procurement in five geographic clusters, to achieve cost reductions via standardisation and economies of scale. These five clusters comprised:

1. The Benelux countries
2. France and Southern Europe
3. The German speaking countries including Northern Italy
4. Northern and Eastern Europe, and
5. The UK and Ireland.

As part of JIVE, both the German speaking cluster (with four sites) and the UK/Ireland cluster (three sites) published joint tenders.

The latter was successful and resulted in a framework agreement with two bus manufacturers to provide vehicles on a call-off basis, with a common specification and the option to tailor buses according to local needs. This framework was live for five years from 2018 and could also be used by sites from other countries to order their FCBs. However, comments from the participant sites suggest that the process was very involved and led to considerable additional administration costs to the sites, particularly at the lead site, which at least partly offset the lower price per vehicle that was achieved.

The joint tender by four members of the German speaking cluster was partially successful. Only two of the sites, the Cologne region and Wuppertal, just some 50 kilometres apart, received an offer and proceeded based on the original tender. They finally placed an order for 40 vehicles. The other two sites tendered individually. Cologne regional transport (RKV) subsequently followed this with another order for 100 buses (May 2022), the largest single order for FCBs in Europe at the time.

Recommendations about following a cluster approach can be found in Table 3-4. There was also some cooperation with respect to procuring HRSs, but this did not result in any joint tendering. Again, the advantages and disadvantages of different approaches and different supply arrangements should be considered in the context of any long-term plans for FCBs and other vehicles in the region.

Sources of further information for the Procurement Stage are listed in Table 3-5.

The original five clusters have now morphed into seven. Figure 3-1 illustrates these groups as of April 2024. Contact details for some of the clusters and some national initiatives can be found in Table 3-6. For countries and regions without contact given, please refer to the European contact.

**Table 3-4: Procurement of FCBs – Challenges and Best Practice Solutions.**

| **Challenges** | **Best Practice Solutions** |
|---|---|
| **1. Developing Tender Documents** | |
| • Design and specification of tender document:<br>Lack of mutually recognised guidelines for technical specifications for FCBs (standardisation); e.g. concerning fuel consumption<br>• Joint Procurement:<br>Specifying the buses so that they meet the requirements of all the partners/sites involved<br>• Project Requirements:<br>Complying with the rules of third party co-funded project created some difficulties<br>• Sticking to Tender Laws<br>while procuring a new technology in an immature market environment<br>• Ability to Collect Operating Data from the Buses<br>i.e. to integrate new data streams of 'electrical machines on wheels' into PTO's regular IT system, including for determining state of health / monitoring of batteries (as for BEBs) | • Put responsibility into the hands of the PTO to undertake the purchase through normal purchasing arrangements. They have both leverage with suppliers and understanding of their own operating requirements<br>• Preferably work in with a PTO's investment cycle and be prepared to support them with advice on where to source information about the new technology<br>• Consider using an existing framework for Joint Procurement from an experienced site as a template/starting point for defining e.g. bus specifications, order process and terms & conditions<br>• Negotiation and communication with suppliers are critical throughout the tender process; due to lack of experience in this area, the purchaser is reliant on the suppliers to validate assumptions and provide input as to the most efficient way to procure the FCB, particularly with respect to the supporting services (maintenance & training); use an RFI process<br>• Address data collection/data provision thoroughly (see learnings documented in Section 4)<br><br>In the event of starting a Joint Procurement with another site(s) with a similar context and requirements (i.e. generally NOT across national boundaries):<br><br>• Partners need willingness to compromise on common bus specifications.<br>• Appoint a single coordinator for discussions and later negotiations with suppliers.<br>• Using a contract framework to be used by the joint tenderers is the best approach as they specify the contract conditions before tendering - once these are in place, the contracts are relatively simple to put in place<br>• It is critical to develop a framework that is scalable and allows for all interested cities to use it, as it provides suppliers with a level of security over the volume of buses to be procured despite the non-committal nature of a framework |

**Table 3-4: Procurement of FCBs – Challenges and Best Practice Solutions (continued).**

| 2. Selecting Supplier | |
|---|---|
| • Lack of Competition/Supply: Manufacturers unresponsive to tender (tenders of under ten vehicles seem to struggle attracting interest); purchaser at a disadvantage; delivery time negotiations can be difficult<br>• Matching proposal specifications with tender specifications: Technology offered not meeting expectations, e.g. buses equipped with a combination of fuel cell and battery with insufficient power to cope with operation in a hilly environment<br>• Suppliers offering different prices in different locations for similar sized orders, because of factors related to the bus specifications, including liabilities, warranty and damages, and the ease of providing maintenance services.<br>• Maintenance costs can increase significantly after around the third year of operation, due to increasing replacement/refurbishment costs of some components.<br>• Evaluating responses requires expertise in $H_2$/fuel cell technology | • Good communication with suppliers and flexibility to negotiate are critical throughout the tender process<br>• Negotiate add-ons once manufacturers have placed bids<br>• Some manufacturers more able/willing, to lower prices in response to scale<br>• Source expertise on the innovative aspects of the technology – experienced sites may be able to assist with this |
| **3. Developing Contracts** | |
| • Lack of Competition/Supply: Price negotiation; delivery time negotiation; suppliers' side can dictate the negotiations/conditions<br>• Lack experience in procuring FCBs: Technical and legal details<br>• Joint Procurement: Contract needs to allow for multitude of variations on the service offering which increases risk to suppliers; multiple stages of review required prior to suppliers accepting the framework and call-off terms as well as agreeing roles and responsibilities in terms of risk<br>• Fuel Cells: Reassurance needed that FC stacks will last | • Absolute clarity is required between all parties on outcomes wanted and compliance with tender/contract details especially where there are sub-contractors involved<br>• Specify maintenance: set expectations for timeliness and expertise, define contracts, assign responsibilities (PTA/PTO/supplier); a full maintenance contract in the early years can be helpful for the PTO<br>• Include a requirement to work with HRS supplier<br>• Models of 'fuel cell as a service' where bus manufacturer/component supplier agree to replace FCs for free if there is unplanned damage are being explored, as is separating the FC warranty from the other parts of the vehicle |

**Table 3-5: Procurement – Useful Resources.**

| Resources | Where to find the Resources |
|---|---|
| Talking to FCB and HRS suppliers and question them on their product specifications and experiences | For lists of suppliers see: https://fuelcellbuses.eu/suppliers<br>or search the membership list of: https://www.hydrogeneurope.eu/directory/industry<br>If possible, visit their factory and use your performance criteria to question them on performance. |
| Talking to and/or visiting sites with operating FCBs and HRSs | For JIVE/JIVE 2 sites see Figure 0-1 or:<br>https://www.fuelcellbuses.eu/projects/jive and https://www.fuelcellbuses.eu/projects/jive-2<br>The authors of this report can provide personal introductions, see their e-mail addresses on page 2. |
| Reports from JIVE/JIVE 2 and from other ongoing and from completed projects | On https://fuelcellbuses.eu/publications for example:<br>• Operators' guide to fuel cell bus deployment (JIVE/JIVE 2)<br>Documents with collation of training materials for staff involved in bus operation, for HRS users and for first re-sponders will become available in 2024. |
| Other reports on planning for HRSs | On https://fuelcellbuses.eu/publications for example:<br>• Recommendations for hydrogen infrastructure in subsequent projects (CHIC)<br>On https://cordis.europa.eu/project/id/671426/results/ (Reports from the NewBusFuel project) for example:<br>• Guidance document on large scale hydrogen bus refuelling<br>• Strategies to ensure adequate redundancy<br>• Agreed definition of availability for bus depot fuelling stations and recommendations |
| Other reports on planning for FCBs | On https://fuelcellbuses.eu/publications for example:<br>• Lessons learnt from joint procurement of fuel cell buses (JIVE)<br>• Final report on the strategies for joint procurement of fuel cell buses (Report for the FCH JU, now the Clean Hy-drogen Partnership)<br>On https://cordis.europa.eu/project/id/671426/results/ (NewBusFuel project):<br>• Common bus operator requirements for future tendering processes (focus: links/interdependencies FCBs/HRSs) |

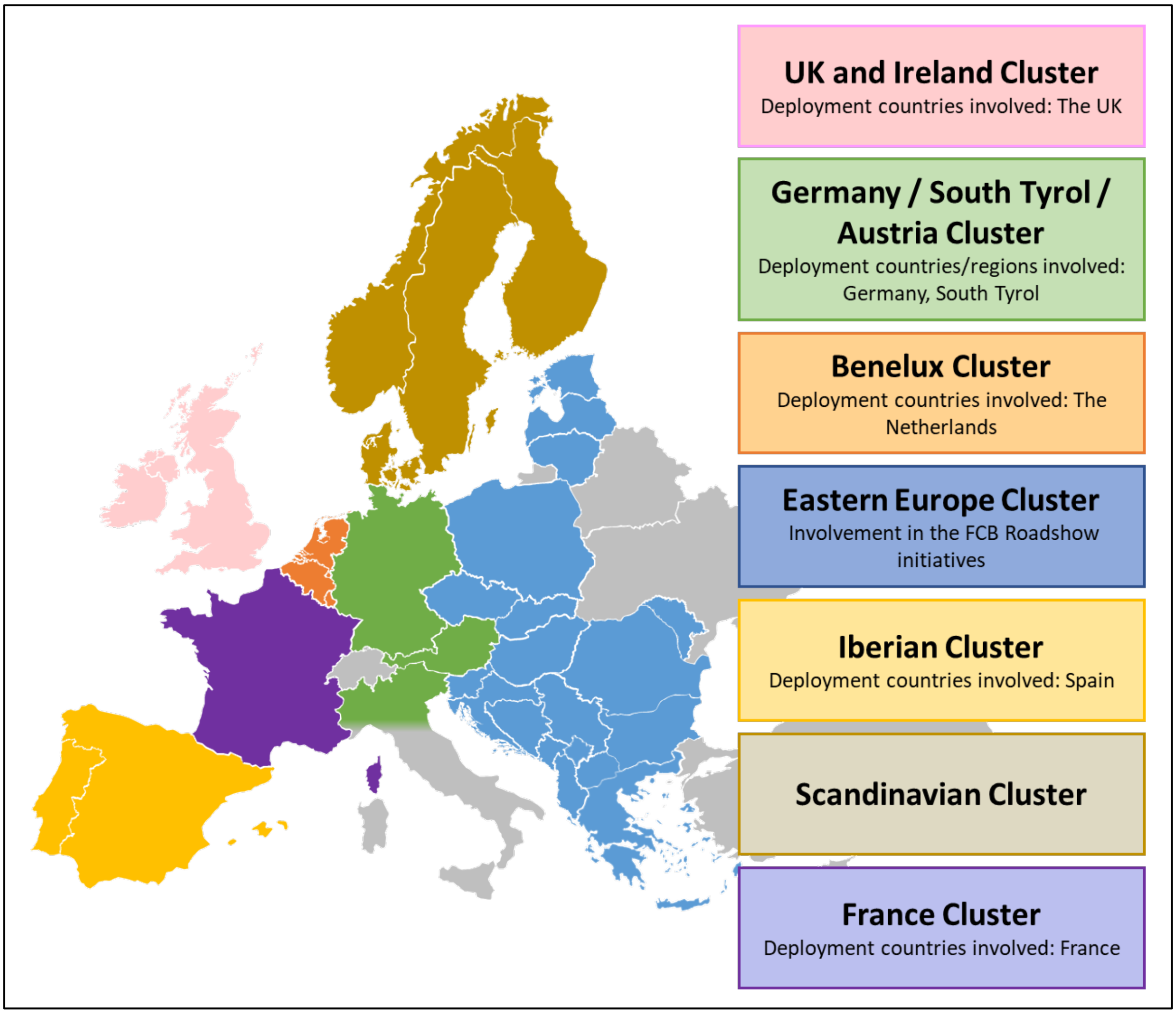


**Figure 3-1: Map of the seven regional clusters to advance FCB deployment.**

**Table 3-6: Contact details for regional and national fuel cell bus groupings.** As of April 2024.

| Cluster / Country | Contact |
|---|---|
| Benelux | Rebel Group – within JIVE, mainly for The Netherlands:<br>Marc van der Steen and Wouter Tettero, Marc.vanderSteen@Rebel-group.com, Wouter.Tettero@Rebelgroup.com,<br>WaterstofNet – outside of JIVE, whole Benelux:<br>Stefan Neis, stefan.neis@waterstofnet.eu |
| Central and Eastern Europe | Latvian Hydrogen Association:<br>Aivars Starikovs, aivars@h2lv.eu |
| French | ERM: Elise Ravoire, elise.ravoire@erm.com |
| Germany / South Tyrol / Austria | Energy Engineers: Frank Koch, koch@energy-engineers.de |

| | |
|---|---|
| Scandinavia | Vätgas Sverige: Björn Aronsson, bjorn.aronsson@vatgas.se |
| Spain | ERM: Eva Baker, eva.baker@erm.com |
| UK and Ireland | ERM: Michael Dolman, mike.dolman@erm.com |
| Europe-wide | UITP: Flavio Grazian, flavio.grazian@uitp.org (JIVE User Group) |

# 4 Stage 4: Deployment and Operations

## 4.0 Introduction

At the date of collection of the information in this Section (up to January 2024), most of the JIVE and JIVE 2 sites had concluded the Procurement Stage and had entered the Deployment and Operations Stage. This project stage is discussed below in the following sub-stages (see Stages Diagram, Figure 0-2):

- **Deployment** – This sub-stage consists of preparatory activities that need to be undertaken before a site can commence operating FCBs (Section 4.1).
- **Commissioning and Early Operations** – This sub-stage discusses the experiences during the very early months of operating the buses and the HRS, including any teething issues (Section 4.2)
- **Regular Operations** – This sub-stage refers to the regular, routine operation of the buses and the HRS as a combined system (Section 4.3)

By January 2024 all 15 sites had reached the Regular Operations sub-stage.

With a few notable exceptions, the Deployment and Operations Stage has proceeded more smoothly than the 3 previous stages, despite some PTOs experiencing a few difficulties during Commissioning. A significant number of these issues were in the standard components in the buses and not in the FC System. Delays in establishing reliably functioning HRSs have also arisen. Ensuring that $H_2$ supply meets the full operational demand has also sometimes been problematic as has been the H2 price.

Where buses are now in Regular Operations, sites are reporting acceptance and high satisfaction from users such as drivers and passengers.

A key message across this and all Stages continues to be that regular, focussed and well organised communication between the relevant parties, including those inside the depot, suppliers, and among project stakeholders is critical (see Section 1.3).

Sites are also reporting that getting the FCBs on the road seems, in some cases, to have acted as stimulus to initiating synergies in related activities. In some regions, FCB projects have acted as a springboard to develop and broaden the introduction of other FC vehicles such as trains, waste trucks and local logistics vehicles outside the JIVE projects framework. Renewed vigour in improving the attractiveness of Public Transport has also been reported.

**MOST IMPORTANT RULE FOR DEPLOYMENT AND OPERATIONS STAGE**

From the moment contracts are signed and throughout all the sub-stages of Stage 4, have continual communications with the FCB supplier, the HRS supplier and the hydrogen fuel supplier. In addition, facilitate all suppliers talking to each other.

It is much too late once the buses and infrastructure are in place to find out that they will not interface efficiently and effectively. Even worse, that no supplier takes responsibility for that breakdown, each pointing at the other.

## 4.1 Sub-Stage: Deployment

This section provides information on the challenges and solutions of a range of preparatory activities that need to be undertaken before a site can commence operating FCBs. Figure 4-1 provides a rule-of-thumb timeline for these preparations based on the experiences of one of the JIVE sites and on the experiences in previous projects. At present a 15 months duration of this Deployment sub-stage can be expected under optimum conditions. That is partly governed by long lead times for the delivery of FCBs and HRS. This is expected to reduce as suppliers gather more and more experience and increase production volumes and the new technology becomes part of regular supply chains. However, the local conditions also play a role. If hydrogen is produced on site, the approval process for the HRS is likely to take more time and effort. The same applies when large amounts $H_2$ are stored.

Major elements of the Deployment sub-stage are addressed in the following tables. These are:

- Depot Modification/Upgrade (Table 4-1)
- Refuelling Infrastructure (Table 4-3)
- Route Planning (Table 4-4)
- Awareness Raising and Training (Table 4-5)
- Table 4-13 lists useful resources for all sub-stages under Deployment and Operations.

Numerous of the challenges and solutions mentioned in these tables are matters that are best dealt with, or at least planned for, during the Financing and Planning Stage. The attentive reader will therefore notice that many of them have already been addressed or mentioned in Section 2. However, the experience of sites is that some of these matters have only come into focus or have needed to be re-visited much closer to the time when delivery of the buses comes into view. Repeating some of them as part of this overall stage is therefore considered to be useful.

As reported in Table 2-5 on HRS planning, hydrogen supply and hydrogen refuelling processes can fail, leaving the buses without fuel. The problems and consequences often only come into focus during the Commissiong and Early Operations sub-stages. However, they need to be addressed beforehand, during Deployment – which is why they are first dealt with in this sub-section, if not already done so during the Financing and Planning Stage. Having backup solutions in place means that e.g. test runs of the buses can be carried even if completion of the regular HRS is delayed. Backup fuel supply can also be important during Regular Operations.

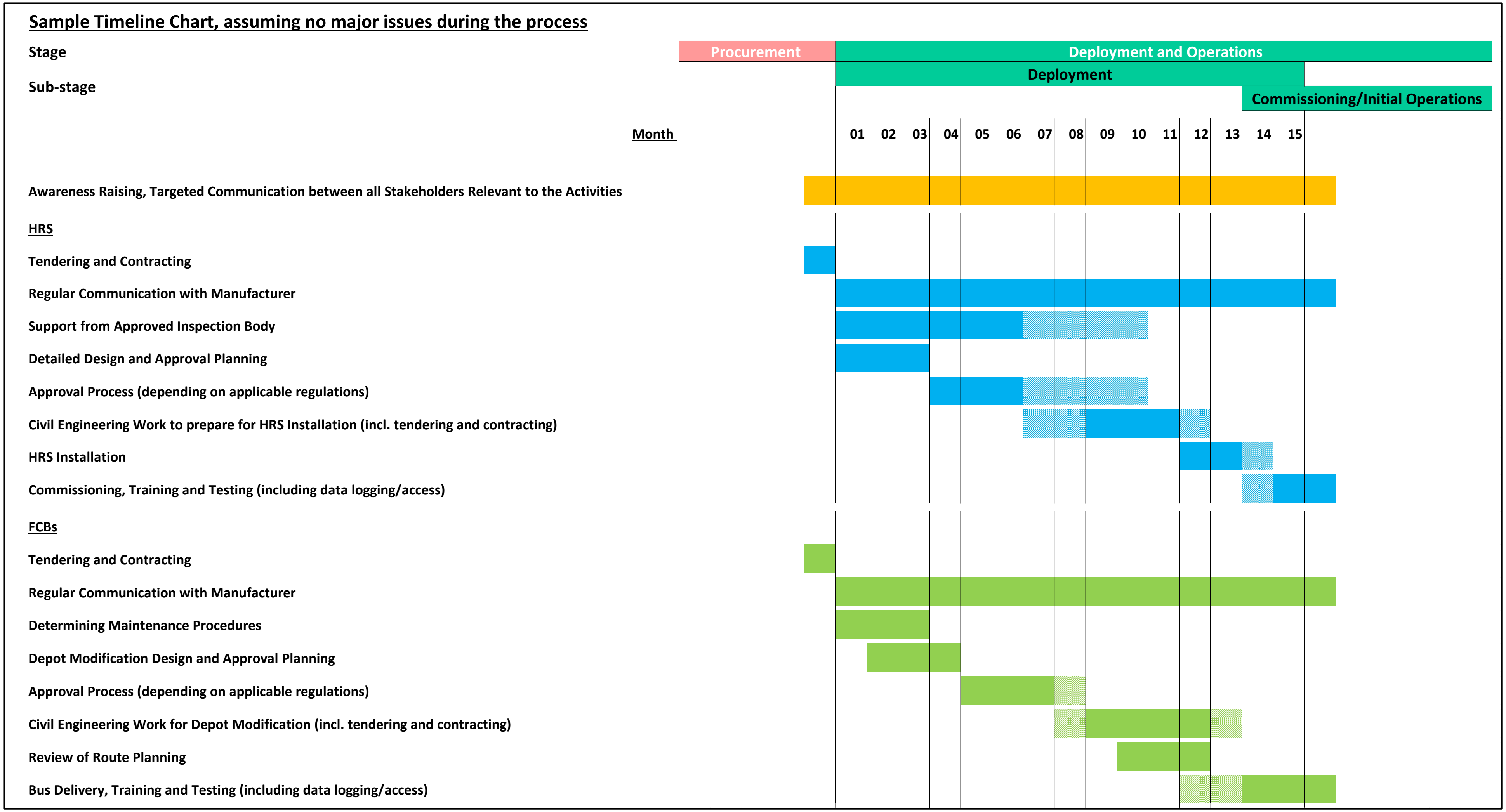


**Figure 4-1: Indicative Timescale for the Deployment sub-stage.**
Striped periods indicate possible extra time needed or potential for an earlier start. Based on a chart developed by Regionalverkehr Köln and expanded with their support.

**Table 4-1: Deployment: Depot Modifications – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Parking:**<br>• Determining how to configure FCB parking along with diesel parking and BEBs<br>• There are no standards for depot adjustment as every depot is configured differently | • Today, some FCBs still require a cable connection for FC freeze protection. That is expected to be obsolete in the future, in moderate climates (western/central Europe) at least<br>• A "safe" parking area may be required for buses that are awaiting checks for (suspected) $H_2$ leaks etc. Also, for purge of the H2 tanks |
| **Bus Maintenance Facility:**<br>• Making a choice between a wide range of possibilities from basic retrofit to new customised facility, to contracting out maintenance to external offsite service provider | • Cost can often determine the choice of maintenance facility upgrade that is made. However, if FCBs are to be the bus of choice into the future, this cost should be amortised over a sufficiently long period<br>• Costs varied widely in the CHIC project due to the differing contexts of the sites e.g., available financing, available footprint, pre-existing infrastructure, safety concerns etc.  gives an overview of some key cost items |
| • There is a distinct range of tools required for working on FC Buses. At times these have been hard to source<br>• Lack of standards or "How to" Guide for hydrogen-ready retrofits and new facilities<br>• Permitting in this area is still developing and authorities still uncertain in this area causing delays | • Make sure you have tools for maintaining FCBs as part of the maintenance deal<br>• The JIVE projects will produce a Guideline for FCB Maintenance workshops that can inform both a retrofit as well as a customised facility. In addition, there are safety specialists who have experience of FCB workshops and can assist with a safety audit that complies with local certification requirements. When in doubt stay on the side of caution<br>• Retain backup diesel buses for some months after operations begin<br>• As has been the case for bus depots previously:<br>**Well-designed depots and well-trained staff = safe operations.** |

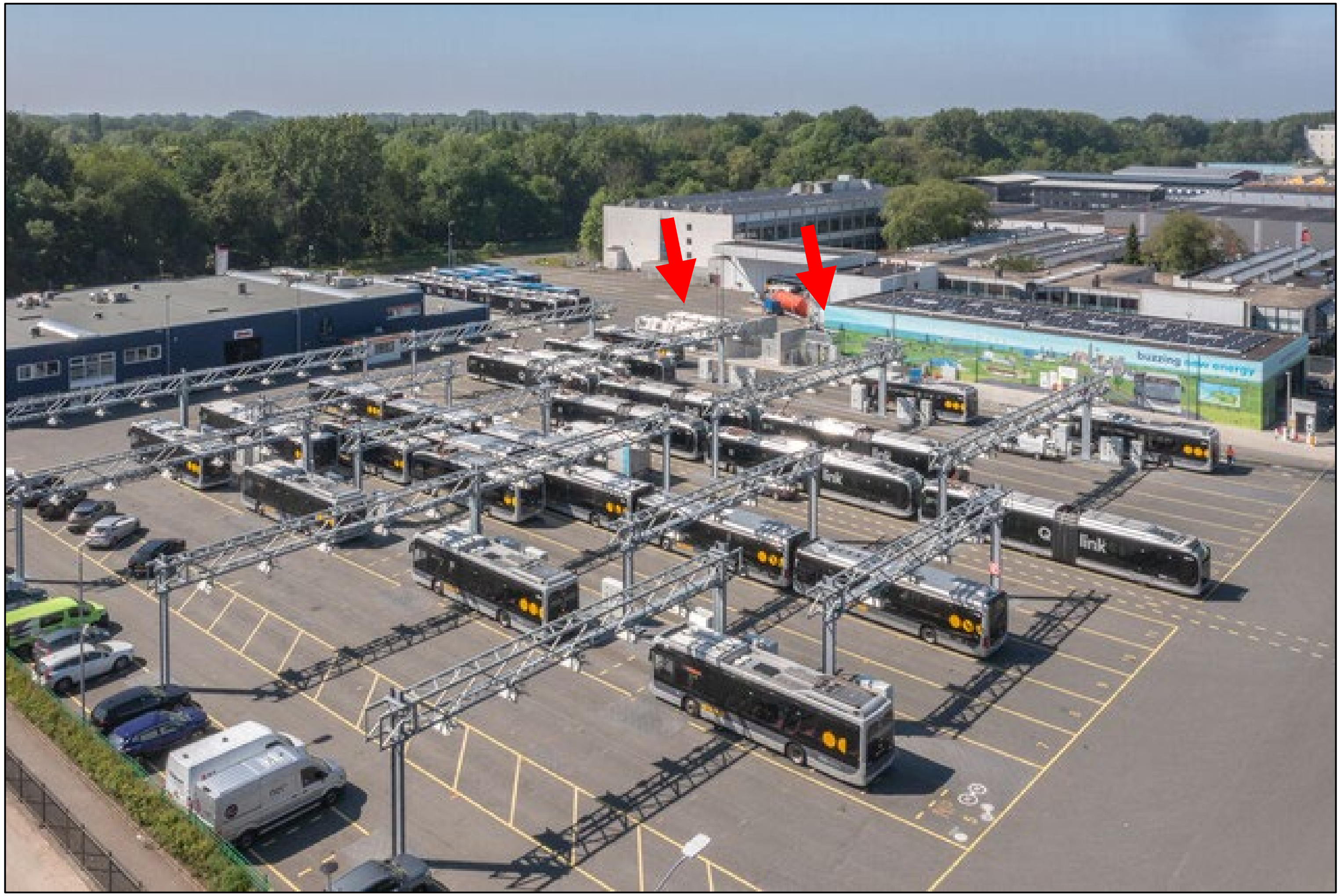


**Figure 4-2: Sample layout of a functioning depot at Peizerweg Depot Groningen, The Netherlands / 1.**
Photo shows the depot parking facilities for BEBs with 72 pantograph overnight chargers in front. The left arrow indicates the parking bays for two hydrogen supply trailers, the right arrow the location of the hydrogen compressors; see also next Figure. Photo by permission of OV-bureau Groningen Drenthe.


**Figure 4-3: Sample layout of a functioning depot at Peizerweg Depot Groningen, The Netherlands / 2.**
Photo shows on the left the two hydrogen compressors in front of the washing hall (with staff in high visibility vest) and towards the right the two hydrogen dispensers. Figure 4-7 shows one of them in more detail. Photo by permission of OV-bureau Groningen Drenthe.

**Table 4-2: Deployment: Cost ranges of some key element when fitting a workshop for servicing FCBs.**
From "Analysis of investments in workshops for fuel cell buses and hydrogen refuelling stations", CHIC Project D3.11, 2015, see Resources in Table 4-13.

| Part | Investment cost [€] |
|---|---|
| **1. $H_2$ specific incremental investment cost for workshop equipment per bay:**<br>A) Retrofitting under ideal conditions (some existing components like existing ventilation for example) | 30,000 to 60,000 |
| B) $H_2$ specific investment cost for the workshop under normal conditions (applying $H_2$ sensors, ATEX lights and ventilation, emergency venting etc.) for 12m standard bus bay | 75,000 to 100,000 |
| C) $H_2$ specific investment cost for the workshop under normal conditions (applying $H_2$ sensors, ATEX lights and ventilation, emergency venting etc.) for 18m articulated bus bay | 190,000 to 230,000 |
| **2. Changes to the workshop structure**<br>Extra windows or fire protective doors | 5,000 to 15,000 |
| **3. Rooftop working:**<br>A) Simple mobile working platform for rooftop working | 5,000 to 15,000 |
| B) Technically sophisticated solution for rooftop working covering whole length of the bus and moving hydraulically around the bus | 90,000 to 150,000 |
| **4. Power outlet** for overnight power supply at parking space | 1,000 to 1,500 per power outlet |

**Figure 4-4: HRS with on-site hydrogen generation in Pau, France.**
$H_2$ production and storage facility is shown at the left of photo. Buses are sequentially refuelled overnight at their parking bays. Photo by permission of Syndicat mixte Pau Béarn Pyrénées Mobilités.

**Table 4-3: Deployment: Refuelling Infrastructure Construction – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Location**<br>The footprint of HRSs can be large when the hydrogen is produced on the same premises and will take up depot space which some sites may not have. For this reason, and for the reason of cost-efficient production of green hydrogen (avoiding certain levies on electricity by placing hydrogen production next to green power production), a few sites located their HRS outside and at distance from the depot. It was only during deployment and early operations that the effort required for refuelling the FCBs remotely (time, staff) became fully clear. As a result, some of the sites had to re-think their approach | • When deciding the location of the HRS, have regard for the time taken to take buses to refuel off-site and any additional resources required<br>• Location needs to consider possible future expansion<br>• There are good resources to help a site decide what is the best option for their situation (see Table 4-13) |
| **Backup planning**<br>Sites have encountered frequent refuelling failures of:<br>• $H_2$ supply (difficulty sourcing $H_2$, problems with timely external delivery, problems with on-site generation)<br>• HRS equipment (compressors/piping/refuelling nozzles)<br>• Reliable filling of the tanks to the required pressure (data transfer Bus → HRS, see Table 4-9)<br>• Long times to fill (software/precooling) | • Have a Plan B (backup) refuelling arrangement – ideally mobile (trailer) and/or have access to multiple HRSs. Redundancy in HRS components is not always sufficient<br>• Undertake a failure modes, effects, and criticality analysis (FMECA) to identify potential failures in systems and equipment to determine their effects and prioritise them based on how critical they are<br>• Have a dedicated technician in the first months of running refuelling arrangements |
| **Permitting**<br>While most sites started this process during earlier stages, many were still involved in lengthy permitting negotiations well after their FCBs arrived. This involved sites having makeshift arrangements all of which made refuelling more complex | The lack of universal standards for hydrogen refuelling arrangements has required each site to negotiate with local authorities. Because the latter may have no experience with HRS it is important to **engage early and often** on this topic. Consider Table 2-4, item 9: "Educate your regulator" It is also useful to **learn from others** who have operated HRS, particularly if they are in your region or country |

**Table 4-4: Deployment: Route Planning – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| • FCBs may have permitting issues for travelling through tunnels | • While this should not be a problem in the future, undertaking a route inspection to determine any safety or operational hazards that may arise can be helpful. In some cases, this has been mandated by permitting authorities<br>• In the case of a private road, tunnel or ferry, the owner may apply individual requirements |
| • FCBs often have much of their FC components on the roof and are therefore taller. This can be an issue for constrained height areas (e.g. bridges, overhanging branches) | • It is recommended that all routes are examined and tested |
| • FC Buses that run on longer routes, or hilly routes have sometimes been found to have issues with the battery running empty due to inappropriate software settings for re-charging the battery from the fuel cell | • The JIVE projects have tested FCBs on a wide range of routes including inner city; cross boundary routes (inner city – residential – semi-rural). They have also tested buses on a wide range of topographical settings from hilly medium runs to flat long run to long run with many stops. Generally, few problems have been encountered<br>• In some cases, the charging regime needed adjusting to allow for faster, longer runs or for hilly routes |

**Table 4-5: Deployment: Awareness Raising and Training – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| In general, awareness raising and training have not presented major challenges<br>• The topics to be addressed/focussed on vary from group to group<br>• Groups that require general <u>awareness raising</u> about FCB:<br>➢ All PTO staff<br>➢ General public<br>• Groups that require FCB (including safety) <u>training</u>:<br>➢ Maintenance technicians<br>➢ Drivers<br>➢ Refuelling/Cleaning staff<br>➢ First responders (Emergency Services)<br>➢ All depot staff – safety basics<br>• Refresher training needs to be scheduled for those most involved to pick up on new employees<br>• Challenges noted include:<br>➢ Refuelling personnel using phones while refuelling<br>➢ Safety procedures do not always stand up to real life situations | Clearly there are technical differences with FCBs compared to diesel vehicles (e.g. high voltage components; handling of devices containing $H_2$)<br>• Map the training requirements, possibly per group. Figure 4-5 gives an example of how this can be done<br>• It is important to familiarise PTO employees as early as possible with the FCBs, affected staff should be given safety training ahead of the bus arrivals<br>• Similarly, the public need to be included in a campaign of <u>awareness raising</u> about $H_2$ fuelled transport. Myths still abound about the safety aspects of $H_2$ and these need to be addressed as do the positive aspects of this clean energy for mobility<br>• <u>Training</u> is conducted through on-line learning, in-person workshops and practical experience. For safety procedures, run exercises/drills<br>• Sites have adopted a range of approaches for providing the training including:<br>➢ Training provided directly by the FCB/HRS suppliers<br>➢ Train the trainer by FCB and/or HRS suppliers with onsite specialist remaining for a time<br>➢ Training provided by the PTO with assistance from the FCB/HRS suppliers (train the trainer and/or materials)<br>➢ Training provided by the PTO with assistance from the FCB/HRS suppliers and involving local/regional training institutions as a means to integrate the information into the formal training system<br>**When developing and undertaking training – factor in a strategy to evaluate its effectiveness** |

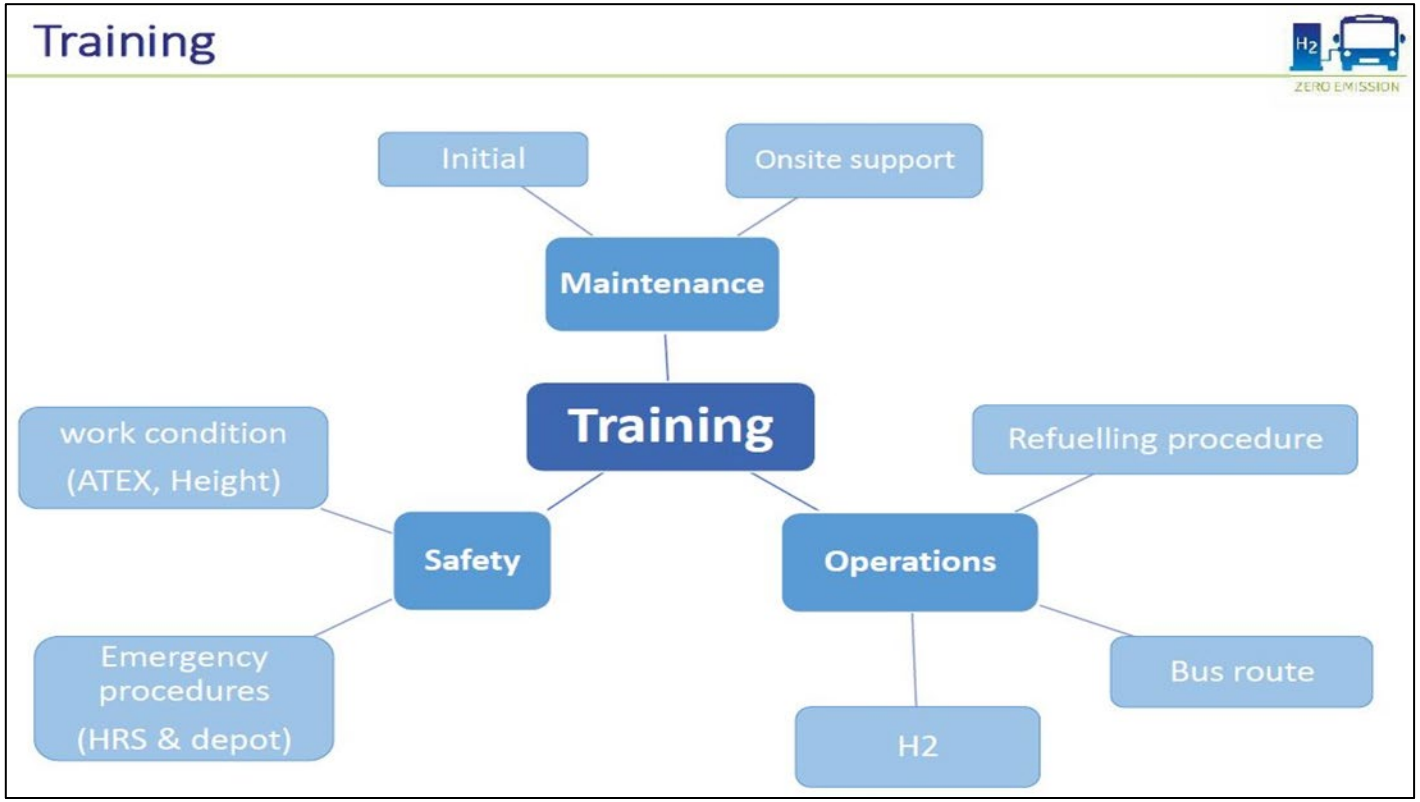


**Figure 4-5: Sample 'Mind Map' of Training Requirements.**
Source: Syndicat mixte Pau Béarn Pyrénées Mobilités.

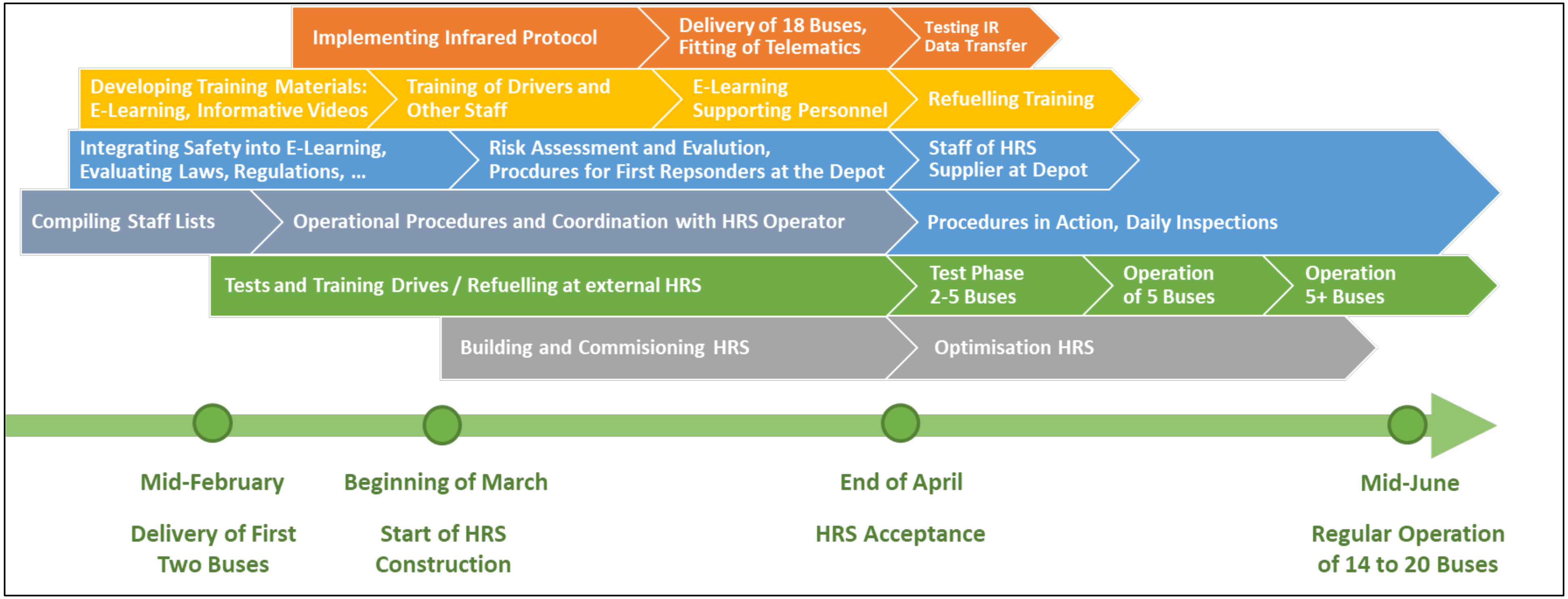


**Figure 4-6: Staff Training in Context: Sample Plan.**
Based on a chart developed by Qbuzz with their permission. Qbuzz operate FCBs in the Dutch Provinces Groningen und Drenthe. Timelines are indicative and will depend on local conditions.

## 4.2 Sub-Stage: Commissioning and Initial Operations

This sub-stage refers to the very early months of running the buses and the HRS. Once they are ready to operate, it is likely that teething issues will arise as in any new equipment (see Table 4-6 through to Table 4-9). Safety in Operations receives a special focus of its own. The safety record of FCBs has proved impeccable to this point, however attention to safety will always remain key, very particularly in these early stages of widespread usage (Table 4-10).

PTOs will also need to integrate data collection and analysis from a new type of vehicle and refuelling infrastructure into their regular IT system and procedures to ensure smooth planning, servicing and operation. The bus and HRS supplier must be contracted to provide these data (see also Table 2-4). With co-funding from public sources, additional data collection and analysis may become necessary beyond PTOs' usual requirements, to be able to prove quantitative project targets have been met.

**Table 4-6: Commissioning and Initial Operations: FCBs – Challenges and Best Practice Solutions.**

<table>
<tr><th>Challenges</th><th>Best Practice Solutions</th></tr>
<tr><td>

**Performance / Technical Issues/Faults**

Standard Bus components

The issues reported have been more to do with the standard bus components or the electrical system than with the $H_2$/FC related components. For example:

- Coolant pressure
- Malfunctioning doors /lights

Electrical System

- Drive train wiring
- Power distribution unit incorrectly installed

FC Propulsion System

- Different starting process of the FCBs compared with diesel buses
- New symbols and (error) messages at the driver-dashboard

</td><td>

- Expect and be prepared to overcome faults collaboratively with FCB supplier
- Testing phase should be adequate for a new technology and the planned work cycle and route (see also Table 4-4). Once the bus has passed this phase, they should perform equivalently to any other bus (diesel or BEB)
- If bus testing is local, then test close to the depot so that return to base can be easier if faults are discovered. Alternatively, some sites have chosen to test at the manufacturer's premises but test with local conditions in mind, e.g., fully loaded with hill starts
- Arrange timelines so that about 10% of the buses are delivered some months ahead, to have most 'teething issues' cleared away before the rest of the order arrives
- Set up regular communication arrangements between onsite technicians/drivers/operators and the supplier in the early stages
- If FCB supplier and HRS supplier have not worked together before, expect issues with refuelling to arise during this sub-stage
- Have the appropriate expertise on hand to answer queries

**Bright Idea: Close the Feedback Loop**

One site made the following suggestion:<br>Have a weekly presence of a technical inspector from the manufacturer when the first vehicles to arrive are tested. This person can report back any changes that need to be made in the bus production line. This ensures real time updating of FCB construction.

</td></tr>
</table>

| Data Logging / Data Delivery | |
|---|---|
| • Data collection software does not all deliver the operational data required<br>• No access to CAN Bus data<br>• Faulty data logger and no authorisation for the data logging dashboard, so that possible data issues could not be checked<br>• Not all the required data in the dashboard available<br>• Dashboard was not ready at the beginning of operations<br>• Poor Wi-Fi connections | • Find out early about the most useful data collection software (and prescribe an adequate system in your tender documents)<br>• Aim for one system for all buses, otherwise you may have different systems / dashboards with different data point availability for every individual supplier<br>• Make sure that the data system can be integrated with other operational systems, such as depot planning<br>• If data availability and provision is not adequate, keep the final retention payment until this is resolved<br>• Be in regular contact with the relevant person whose role it is to carry out updates or swaps of the data logger and chase them early |

**Table 4-7: Where Route Planning, Training and Safety Intersect: A Recent Incident.**

## A Recent Incident

One site, for which the routes had been carefully planned, had an incident where the top of an empty bus returning to the depot hit the bottom of a low bridge. This was the result of a driver deciding to take a “short cut” back to base (https://www.rtvdrenthe.nl/nieuws/16246527/streek-bus-klem-onder-viaduct-bij-wijster). Due to components on the roof, FCBs are often taller than their diesel counterparts and this was a deviation from the careful route planning.

This incident highlights some important lessons:

- Training of drivers must ensure they understand FCB differences and **emphasise** the importance of taking only approved routes (although this had been covered in the driver’s initial training)
- The hydrogen tanks withstood the impact well and safety valves isolated the vessels that still contained hydrogen. A pressure gauge downstream the safety valves signalled ‘0 bar’. While the situation was safe in this respect, fire service/emergency services staff need to be aware that a ‘0 bar’ reading at one point of the piping does not necessarily mean that all elements of the system are pressureless/empty.
- Even though the main electricity switch of the bus was turned off, the high-voltage electrical system on the roof remained ‘live’ and the fire service/emergency services’ lack of experience with FCBs could have created a dangerous situation. Fortunately, the head engineer intervened before any harm occurred. This again despite significant efforts to educate the first responders.

**Table 4-8: Commissioning and Initial Operations: FCB Maintenance Procedures – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| • Acquiring maintenance expertise for FCBs. New technology needs to be watched and problems pre-empted.<br>• The training for FCBs is a "step up" from that needed for BEBs. | • Most FCB operators have their own maintenance technicians trained by the bus supplier and supported for a period of time on site by the supplier's technician/s. After that period, the supplier in many cases have provided 'flying doctor' support. See Table 4-5 for more information on Awareness Raising and Training. One site has fully outsourced their maintenance as they do for diesel buses<br>• During the early commercial deployment of FCBs, geographically close operators should consider pooling their maintenance technician resources<br>• Oversight by the manufacturer of local maintenance activities may be required for a time to ensure the adequacy of servicing. |
| • Scheduling of FC Buses for maintenance | • Some sites have chosen to adjust (shorten) their preventative maintenance schedule intervals and contents for the new technology for the time being<br>• Manufacturers are starting to use pre-emptive maintenance to monitor when parts are likely to need replacing<br>• Keep existing other procedures adapted for the requirements of a FCB e.g. car wash, indoor fuelling, etc. – these will help reduce costs |
| • Despite maintenance agreements some delays in receiving spare parts have to be anticipated | • This challenge has been a perennial issue, occurring in every FCB demonstration project. Clearly specifying expected timeframes for the provision of spare parts and imposing penalties for these not being met must be in contracts with the FCB suppliers (see Table 2-6 and Table 3-1)<br>• In addition, when the FCBs come from a different supplier than diesel buses in the same fleet, the need for conventional spare parts (e.g. wipers or windows) must be considered |

**Table 4-9: Commissioning and Initial Operations: Refuelling – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Performance / Technical Issues / Faults**<br>HRSs as deployed at the JIVE/JIVE 2 sites are still not standardised or fully mature. Operators have encountered a wide range of challenges, including (as also mentioned in Table 4-3):<br>• Component failure (e.g. compressors – probably still the most troublesome components/dispensers/electrolysers)<br>• Software failures<br>• Unacceptable long duration of fills<br>• Safety check failures<br>• Pre-cooling of the hydrogen<br>• Noise (chiller) and leakage issues<br>• Clear need for backup plan for refuelling | • Testing the refuelling process in slow and careful stages<br>• Check $H_2$ purity at the dispenser outlet after washing the system with nitrogen e.g., during initial start-up, until nitrogen concentration is below its threshold limit.<br>• Having and using backup refuelling arrangements (see Table 4-3)<br>• Be aware that adjacent neighbours may be affected by noise from the compressor or other components<br>• Ensure there is an adequate monitoring system on the HRS with quick response to alarms – specify supplier's response time to problems in hours (see also Maintenance below)<br>• While pre-cooling is still being standardised, one site – in cooperation with the HRS manufacturer – has reconfigured dedicated refuelling protocol tailored to their FCBs to avoid the need to pre-cool as much as possible (at a reduced but satisfying speed of refuelling).<br>• Using contract requirements to ensure ongoing technical support from supplier |
| **Maintenance / After-Sales Service**<br>• Lack of local maintenance expertise and slow response time from supplier to fix issues | • Agreements should include:<br>➢ 24/7 service hotline<br>➢ Remote access to the HRS<br>➢ Local support (incl. flying doctor)<br>➢ Training of local technicians to support maintenance |
| **Bus-to-HRS Data Interface**<br>• Infrared data transmission is still relatively new/sensitive. A lot of trouble shooting on this issue was necessary. | • Data transfer from the bus (tank) to the HRS is important to ensure quick and complete fills. If there is no communication, a more rigorous/conservative fuelling protocol needs to be followed to ensure safe refuelling while slowing down the filling process |

| | |
|---|---|
| • HRS hydrogen nozzles have an infrared sensor connection mounted on them. These can be easily knocked/damaged or for some reason fail to connect with the bus transmitter on the bus<br>• Replacement nozzles are expensive (>€10,000), the infrared sensor cannot be replaced without the whole assembly | • Ensure bus refuelling staff are trained in use of the nozzles.<br>• Put protective measures in place, e.g. rubber mats on the floor where the nozzles are used, to prevent damaging the infrared sensor when the nozzle is dropped accidentally |
| **Data Logging / Data Supply**<br>• Accessing data has not always gone smoothly (technical issues)<br>• Not all suppliers of HRSs are willing to the share data that they log anyway (but which are required by a co-funding entity or for warranty claims or generally for the integration of data flows into the PTO's IT system)<br>• Not all operators are willing to the share data that they log anyway | • Request demonstration of data output and format prior to contracting<br>• Data needs and data supply must be specified in contracts. Ideally contracts should be with the party responsible for producing the data or, at the very least, the responsible party should be nominated and clear to all<br>• Make reliable data supply part of the acceptance test<br>• Include penalties in contracts<br>• In some instances, data from the buses have been used to gather refuelling data as an interim solution to secure meeting (part of the) reporting requirements from the institution providing co-funding |


**Figure 4-7: Hydrogen dispenser at Peizerweg Depot Groningen, The Netherlands.**
Photo shows the second dispenser in front of the washing hall, from a different angle than Figure 4-3. The other dispenser is hidden by a refuelling FCB. Photo by permission of PLANET.

**Table 4-10: Commissioning and Initial Operations – Safety in Operations.**

| **Safety in the operation of FCBs– see also Planning and Procurement in Sections 2 and 3** |
|---|
| In the more than 20 years of European Fuel Cell Bus Demonstration projects, the issue of the safety of the new technology has remained a constant focus. As with all new technologies, each project has developed and refined procedures that have allowed overwhelmingly safe operations.<br><br>Despite that, during the latter part of the JIVE projects there was a case of an empty FCB being involved in a fire. This event was thoroughly investigated and a public report was issued by the local fire department (in the local language). Unfortunately, the bus company has yet to provide details of their report. Given that fire is not unknown in conventional buses, this is not of itself a cause for alarm. However, the incident does serve to remind all that this is new technology that brings together high voltage electricity with ignitable gas under pressure.<br><br>Ensuring various parts of a FCB System (buses/bus operation including maintenance, refuelling and hydrogen supply) has been challenging for some. Insurance companies, as for regulators and first responders have few established, customised protocols to work with, although this is changing rapidly.<br><br>JIVE/JIVE 2 sites have prepared their own Hydrogen Safety Plans from information freely available. These include procedures for $H_2$ leaks and displaying important emergency contacts. Safe operating protocols must always be observed and constantly reviewed.<br><br>The experience drawn from reported incidents in the Hydrogen Incidents and Accidents Database HIAD suggests that particularly attention has to be given to these activities when dealing with hydrogen:<br><br>• Transferring hydrogen from one system to another<br>• Executing repair/maintenance works,<br>• Operating systems manually,<br>• Integrating sub-systems from several providers/contractors (quality assurance, etc.),<br>• Involving non experts (public safety!)<br><br>**Generally speaking: Good Training and Maintenance = Safe Operations**<br><br>To learn about HIAD and to download the dataset, go to: https://minerva.jrc.ec.europa.eu/en/shorturl/capri/hiadpt<br><br>To register an incident on HIAD email: JRC-PTT-H2SAFETY@ec.europa.eu<br><br>See also Resources in Table 4-13.<br><br>Numerous commercial bodies can also advise on Hydrogen Safety in Transport. |

## 4.3 Sub-Stage: Regular Operations

This sub-stage considers the regular operation of the Buses and the HRSs/$H_2$ supply as a combined system. At the time of collection of the information in this Section (August 2023) all 15 sites had started Regular Operations. The sites have reported few issues in transitioning to this phase. They were generally pleased with progress of the FCBs although in numerous cases problems with the HRS availability were stopping buses from operating in regular service.

The reports from the sites included:

- High levels of satisfaction with, and acceptance of, the buses being reported by drivers, technicians and passengers
- Seamless integration with diesel buses - same flexibility and operating procedures
- Good levels of efficiency in terms of fuel consumption, often significantly better than the typical 8-10 kg/100 km with the previous generation of 12 m FCBs. Some local fleets have achieved less than 7 kg/100 km
- Acceptable refuelling times, although not reaching the project target of 3 kg/min.
- Acceptable levels of availability and reliability of FCB and HRS operation reported by operating sites

Table 4-11 and Table 4-12 provide final insights into the challenges faced by the JIVE and JIVE 2 sites in this sub-stage.

Table 4-13 provides resources for the entirety of Stage 4.

| **Watch words for the Regular Operations Sub-Stage** |
| --- |
| **“EXPECT THE UNEXPECTED”** |

**Table 4-11: Regular Operations of FCBs – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Communications**<br>• Managing expectations, primarily of PTO staff and ensuring they are aware that this is new technology and may not always be as close to perfect as are diesel buses<br>• Regular contact with suppliers remains necessary but they can sometimes react very slowly | • If the integration of FCBs has been managed by the PTA, continue regular contact with the PTO to deal with operational issues quickly (if PTO is managing the process, management and staff would be fully aware of these)<br>• PTO should continue regular communications with the bus manufacturer<br>• Share experiences with other operators that operate the same type/brand of FCB<br>• Continue to have an experienced person managing the FCB fleet |
| **Maintenance / Repairs / Faults**<br>• Slow fault finding on bus issues initially<br>• Drivers misdiagnosing faults initially<br>• Long downtimes due to longer delivery times for spare parts, in particular conventional parts (doors, mirrors etc.)<br>• Numerous small problems persist into regular operations | • Involve maintenance personnel in carrying out vehicle acceptance checks, so they learn details and issues early and are not reliant on bus supplier technicians<br>• Utilise manufacturer's predictive software to predict faults before they arise<br>• Ensure a small stockpile of conventional spare parts at site (see recommendation in Table 4-8) |
| **Training**<br>Once in regular operations pools of trained drivers can deplete quickly | • Continue to train additional drivers as well as undertaking refresher training. It is essential drivers are comfortable and confident with handling FCB<br>• Train drivers for driving the FCB on specific routes – the handling may change<br>• Emphasise the need to plug in bus defrost device at end of shift (even in summer) |
| **Data Collection**<br>• Data gathering is still an issue and not all data points are available<br>• Data transfer while the buses are in use was only made possible at a later stage and is currently still being tested | • Early attention to requirements for data (see Table 4-6 for recommendations)<br>• Use data to look for patterns of problems to be able to talk to the bus supplier with data as evidence |

**Table 4-12: Regular Refuelling Operations – Challenges and Best Practice Solutions.**

| Challenges | Best Practice Solutions |
|---|---|
| **Hydrogen Supply**<br>• Supply chain resilience has sometimes been a challenge where $H_2$ is trucked in from an external source<br>• Hydrogen price has been driven up by a number of external factors and has led to some "mothballing" of FCBs | • It is likely that only the access to multiple refuelling sites will fully solve the lack of $H_2$ supply issue. In the meantime, can be advisable to maintain a buffer storage of $H_2$ wherever possible (at extra costs, though).<br>• 'Mothballing' FC Buses will require them to be regularly run (perhaps on rotation) to avoid rusting |
| **Performance: On-site Hydrogen Production Unit (where in place)**<br>• Recurring electrolyser issues (e.g., power conditioning unit, transformer, water leakage, novel PEM stack)<br>**Performance: Refuelling Unit**<br>Problems emerging during Commissioning and Initial Operations often continued, e.g.:<br>• Compressor issues<br>• Refuelling slower than contractual agreement despite pre-cooling<br>• Unreliable/failed refuelling (not meeting specifications for minimum bus tanks pressure/desired state of charge and/or for the maximum duration of a fill)<br>• Slow after-sales service | **Performance**<br>• Detailed fault-finding sessions with HRS supplier to determine faults and fixes for them<br>• Be prepared to invoke penalties if supplier is unresponsive<br>• Have a plan B for refuelling if time to fill requirement is not met<br>• (Temporarily) try to work well within the HRS's limited capacity i.e. time to fill can be less important than refuelling the FCBs to full state of charge (depending on the required daily range and overnight servicing regime in the depot) |
| **Data Logging / Data Supply**<br>Problems reported during Commissioning and Initial Operations have continued | See Table 4-9 |

**Table 4-13: Deployment and Operations – Useful Resources.**

| Area of Interest | Resources and where to find them |
|---|---|
| **Depot Upgrade Information**<br>• Depot arrangement | • https://blog.ballard.com/adapting-bus-depots-for-hydrogen<br>(The author of this article was involved with earlier FCB Demonstration Projects) |
| • Maintenance Facility | • Best Practice Guide for Fuel Cell Bus Maintenance Workshops (currently in preparation, to be found on https://fuelcellbuses.eu/publications)<br>• Indicative Costs of Maintenance Workshop (CHIC project, 2015) https://www.fuelcellbuses.eu/public-transport-hydrogen/analysis-investments-workshops-fuel-cell-buses-and-hydrogen-refuelling |
| • HRS Layout | • https://fuelcellbuses.eu/projects/newbusfuel |
| **Safety** | • JIVE Projects Hydrogen Safety Kit https://www.fuelcellbuses.eu/publicationshttps://h2tools.org/sites/default/files/Safety_Planning_for_Hydro-gen_and_Fuel_Cell_Projects.pdf<br>• Reference Documents of the European Hydrogen Safety Panel https://www.clean-hydrogen.europa.eu/get-in-volved/european-hydrogen-safety-panel-0/reference-documents_en in particular:<br>➢ Simple template for a safety plan Interim publishable version<br>➢ Safety Planning Implementation and Reporting for EU projects<br>➢ Statistics, lessons learnt and recommendations from the Analysis of the Hydrogen Incidents and Accidents Database: https://minerva.jrc.ec.europa.eu/en/shorturl/capri/hiadpt (HIAD 2.1 - September 2023)<br>➢ For questions and specific requests, JRC Hydrogen Safety address: JRC-PTT-H2SAFETY@ec.europa.eu<br>• "Wasserstoffsicherheit in Werkstätten "(DGUV Information 209-072, in German only), published by Deutsche Gesetzliche Unfallversicherung (DGUV, statutory accident insurance in Germany), Berlin, March 2021 https://publikationen.dguv.de/regelwerk/dguv-informationen/265/wasserstoffsicherheit-in-werkstaetten |
| **Training** | • "Training for Work on Vehicles with High Voltage Systems"(DGUV Information 209-093 , revised edition), pub-lished by Deutsche Gesetzliche Unfallversicherung (DGUV, statutory accident insurance in Germany), Berlin, |

| | |
|---|---|
| | June 2023 (also available in German, of August 2021) https://publikationen.dguv.de/regelwerk/dguv-informationen/4727/training-for-work-on-vehicles-with-high-voltage-systems |
| **Hydrogen Safety Myths** | • https://blog.ballard.com/hydrogen-safety-myths (2017/18) |


**Figure 4-8: FCB at the public HRS in Barcelona, Spain.**
Photo by permission of Transports Metropolitans de Barcelona (TMB).

# 5 Issues to be Addressed to Support Full FCB Commercialisation

The gathering of Best Practice information from the participants in the JIVE and JIVE 2 projects has produced numerous insights on how to support the uptake of FCBs. Given that there will be no more FCB demonstration projects like JIVE/JIVE 2, these have become more pressing if the intention is to leave FCBs ready for the commercial market. Tackling these issues could be considered for actioning by the Clean Hydrogen Partnership and/or other European public and private sector groups and organisations, as well as by stakeholders at the national level. In some cases, suggestions are made on how to address these matters. The Clean Vehicles Directive with its mandatory targets for procuring zero emission buses adds weight to the need to address these 'meta' issues sooner rather than later.

### Further Growing and Better Supplying the Demand

1. While there have been some new manufacturers entering the FCB market, this market is still considered far from mature. There are still few European FCB suppliers, with some being relatively small suppliers with limited financial resources. The result is that there is limited competition among FCB bidders.
   Few suppliers currently offer an articulated FCB although there is promise of others doing so. Promoting the demand and the type of demand for FCBs to bus manufacturers remains an important and necessary activity.

2. Some calls for tenders have not prompted any bids at all, particularly for small numbers of buses, and those with complex specifications and options. It was hoped that tendering for larger bus orders, including by means of Joint Procurement, would stimulate the industry. However, the industry has been slow to respond, and it is possible that the orders are still too small to attract additional manufacturers into the market.

3. There appears to be very little uptake of FCBs in the EU-13 Member States. This is almost certainly partly to do with funding issues and lack of promotional activities but also lack of manufacturers selling into the market. It is to be hoped that measures being taken as part of JIVE /JIVE 2 will remedy this situation to some extent.

4. This lack of penetration into the markets in the EU-13 countries is being exacerbated by the imperative of the Clean Vehicle Directive targets. The added expense of meeting these targets needs to be supported by funding at supra-national and national levels. Significant numbers of regions and PTOs are contacting the JIVE/JIVE 2 project coordinator about how to fund meeting these.

Further financial support is needed (possibly through the Clean Hydrogen Partnership's "Hydrogen Valley" concept but with a particular emphasis on clean public transport) and could, for example, concentrate on:

- Large scale FCB implementation through individual site orders of 50 or more FCBs and
- 50+ orders based on Joint Procurement with good support on the national or cluster level, that bundle individual site demands for smaller numbers of buses. This should be encouraged in regions with little activity up to now, particularly from the EU13 new member states. It will be important to ensure that Joint Procurement arrangements do not become overly complicated e.g. by crossing regulatory frameworks or with different group members requiring a large number of vehicle options/variations.
- In line with the principle of "Just Transition" to zero emission public transport, there is a need for options for lower income countries. Retrofits of diesels and the second-hand market of FCBs is very immature.

### Ensuring Experience is Preserved and Better Shared

The 20+ years of FCB demonstration projects will leave an enormous legacy of "know how", much of it embodied in the sites that have committed to FCBs but much of it also in digital documents. Recommendations 5 and 6 are designed to capitalise on this legacy and ensure that for the short term (capped at maybe 5 years), it is easily available to all communities wishing to deploy and operate FCBs.

5. Participants in the JIVE projects say they highly value talking to sites with experience of deploying FCBs as a means of learning. This can come at a cost to these experienced sites when they are approached frequently.
   Providing funding to these experienced sites to compensate them for their work to provide on-going assistance to new entrants might make this learning more accessible to all. These experienced sites could effectively become regional 'Centres of Excellence (CoE).'
   The role of a 'CoE' would be solely to provide information about the deployment and operations of FCBs through accepting visits to their site and discussions with new entrant cities and regions. A sunset clause could be applied to the CoEs to dovetail with the hoped-for widespread commercialisation of FCBs.
6. Written information on the 'how to…' of implementing FCBs, currently held in a central, online repository, is being used but not as much as would be preferable. Information from JIVE participants suggests that two actions might improve the usage of the valuable information that is available:

- Provision of basic information in a range of languages in national/regional online information pools (in addition to the central ones)
- Provision of the information through actively promoted workshop and training events, in cooperation with experienced sites

Currently the UITP is undertaking some of this work under the umbrella of the JIVE/JIVE 2 projects. It is also being undertaken by locally and regionally based clusters, who have the added benefit of being able to present it in their own language.

It is strongly recommended that the 'care' of this significant amount of useful information should be assigned to one party, not as an "add on" but as a paid service. This party could act as a type of library service to new entrants, directing them to the best documents/individuals who could help give them the information they are seeking. Significant resources have already been invested in collecting this information. To preserve it, at least for a set period following the end of the JIVE projects, would seem a value-for-money proposition.

7. Some sites seem to have entered (and have sometimes left again) projects with little understanding on what they are embarking.
   A one-day introductory, mandatory workshop before any city or region new to FCBs can apply for funding/finance could ensure that there is a basic level of insight and reduce the risk of local activities running into easily foreseeable difficulties.

### Providing the Right Frameworks

8. Some HRS tenders faced problems and delays. Sometimes this resulted from suppliers having to tailor their equipment to meet demanding local requirements. While some PTAs/PTOs have become better experienced at tendering appropriately and can share their knowledge, standardisation of HRS outcome specifications is urgent (e.g. dispensing capacity per daily refuelling window rather than HRS on-site storage capacity). Based on experiences gained in the implementation of the JIVE and other projects, HRS manufacturers should now be able to offer a set of basic models/options that PTOs/PTAs and other potential HRS operators can choose from. The fact that at the time of writing they generally do not, suggests more effort needs to go into persuading industry to undertake the necessary development.
   In addition, HRSs have been called the "the Achilles heel of FCB operations". That relates to hydrogen fuel supply to the HRS site as well as HRS technical performance in terms of availability for service (being able to refuel) and reliability in service (refuelling to the desired state of charge within the specified interval of time). Concerted action to improve HRS performance is urgently required.

9. The EU definition for Renewable Hydrogen is now available. What constitutes 'Green' $H_2$ is defined within this. However, reliable supply of green fuel at reasonable costs is considered another hurdle that could turn into a barrier. Cost parity or close to parity with conventional and/or battery buses is of key importance for PTOs. In this context, major industrial players and governments can have a role in setting up and supporting large scale green hydrogen production projects that could supply various end users, including broader industry sectors. Seen from this angle, the prospects of affordable hydrogen in public transport partly depends on the developments in other sectors, namely its bulk use in industry.
10. Permitting and certification of HRSs and bus maintenance workshops is making progress. However, it can still seriously slow down the implementation process.


**Figure 5-1: Buses and HRS in Aberdeen, United Kingdom.**
Top: Part of the double-deck FCB fleet. Bottom: Bus refuelling. Photos by permission of First Bus.

**Project coordination:**

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Clean Hydrogen Partnership

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Annexes to the

# JIVE Final Best Practice and Commercialisation Report (D3.26)

Klaus Stolzenburg, Katharina Buss

# JIVE 2 Final Best Practice Information Bank Report (D3.29)

Nicole Whitehouse, Simon Whitehouse

ZERO EMISSION

**JIVEs / MEHRLIN projects**


@fuelcellbus www.fuelcellbuses.eu

Clean Hydrogen Partnership
Co-funded by the European Union

Main authors: Klaus Stolzenburg (PLANET) k.stolzenburg@planet-energie.de (JIVE)
Katharina Buss (PLANET) k.buss@planet-energie.de (JIVE)
Nicole Whitehouse (Sphera) NWhitehouse@sphera.com (JIVE 2)
Simon Whitehouse (Sphera) SWhitehouse@sphera.com (JIVE 2)

Contributors: All sites via their questionnaire input and via discussions in project meetings and bilaterally

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# Annex A Objectives of the JIVE / JIVE 2 Projects

The JIVE and JIVE 2 projects are closely linked. While JIVE 2 started one year after JIVE (JIVE on 1 January 2017), both projects have similar objectives and are following similar project trajectories. They are also encountering similar challenges and solutions.

The objectives of both projects can be summarised as follows:

- Deployment of 290 zero emission FCBs across Europe (sites map in Figure 0-1)
- Achieve a maximum price of €650,000/€625,000 (JIVE/JIVE 2) for a standard bus (single deck, typically 12 m), advance the commercialisation of FCBs through large-scale deployment of vehicles and facilitate commercial viability for bus operators by the end of the projects (mid-2024/25) to minimize/eliminate need for subsidies
- Operate buses with an average fleet availability of at least 90%, and reduce environmental impact of bus operations by operating fuel cell buses in place of diesel buses for extended periods
- Demonstrate routes to low cost, renewable hydrogen
- Stimulate further uptake of FCBs via a comprehensive, high impact dissemination campaign
- Empower local and national governments to regulate for zero emission propulsion for public transport systems
- Share data and best practice to support the adoption of the technology and provide evidence of the suitability of fuel cell buses for wider roll-out.

The JIVE and JIVE 2 projects also ran in parallel and in close cooperation with the MEHRLIN project, which was funded under the Connecting Europe Facility for Transport. Many of the HRSs for the JIVE/JIVE 2 sites were implemented within the MEHRLIN project. Its overall objective was to demonstrate a financeable demand-led business model for HRSs. MEHRLIN ended on 30 June 2023.

The number and location of sites in the JIVE and JIVE 2 projects has varied over time as some cities/regions have left and new ones have joined, sourced from a reserve list. The reasons for this have ranged from loss of local support due to changes in the political environment as the result of elections, budgetary constraints (e.g. costs turning out to be much higher than excepted than at project proposal stage) through to lack of interest from suppliers in locations remote from their current commercial activities.

# Annex B Information Gathering and Processing Method

The local coordinators of the demonstration cities and regions were regularly requested to provide input, via questionnaires, on their project progress, successes, Challenges encountered and Best Practice solutions found. Seven rounds of questionnaires were used as the basic instrument for gathering information. Added to these were one-on-one interviews with some of the local coordinators along with a number of site visits to gain additional on the ground insights. Other reporting mechanisms and forums within the two projects have been trawled for relevant information as well.

Round 1 questionnaire was sent to all JIVE and JIVE 2 local site coordinators in spring 2018. Because two people responded at three of the sites, there were a total of 22 responses from effectively 19 sites. There were 17 sites at the time. However, Cologne and Wuppertal being involved in both projects were counted separately for JIVE and JIVE 2 in this round because their state of progress was not the same in the two projects, e.g. regarding FCB procurement.)

Ten of these sites were still dealing with Financing and Planning, eight were engaged in Procurement, and preparations for Deployment had started at one site.

In Round 2 in February 2019, there were 18 responses from 17 sites. Construction as part of Deployment had started at one site. All others were working on Procurement, most of them selecting suppliers or developing contracts with them. The 2019 Best Practice Report (JIVE only) was based on Rounds 1 and 2.

In Round 3 in June 2019, there were 18 responses from 18 sites. Most had started working on Procurement. Construction was progressing at one site. The observation that not all sites were at Procurement Stage (as they were during Round 2) is explained by that fact that two sites had to go back to Planning after an unsuccessful round of tendering (no or no adequate offers received) and one that responded in June but had not done so in February. The 2020 Best Practice Report was based on Rounds 1 to 3.

Round 4 in August 2020 consisted of three questionnaires developed to customise questions to the Stage sites had reported reaching. The three groups were as follows:

- Group 1: Sites that had entered the Deployment and Operations Stage (10 out of 10 possible responses)
- Group 2: Sites about to complete Procurement (no contracts signed) (3/4 responses)
- Group 3: Sites that had only recently joined the JIVE projects and were still working on the early stages up to and including Procurement, with additional questions on expectations etc. (3/5 responses)

Round 5 in August 2021 was made up of a single questionnaire with ability to opt out of sections if sites had not reached that stage at the time of surveying. There were 18 responses from 17 sites. The 2022 Best Practice Report was based on Rounds 1 to 5.

Round 6 in August 2022 was made up of a single questionnaire with focus on the Deployment and Operations Stage. Sites were given an option to also comment on any experiences in the past 12 months that related to earlier stages. There were 16 responses from 16 sites.

At the time of data collection 15 sites had entered the Deployment and Operations Stage with 12 already in the final sub-stage of Regular Operations. 5 sites were revisiting the Finance and Planning Stage – some because they had decided to procure more buses, others because they had had tender problems. One site was still procuring and one site was extending their HRS, so were also still in the Procurement Stage

Round 7 in August 2023 was very similar to Round 6, in that it concentrated on the Deployment and Operations Stage. As it was the final round of data collection for both projects, respondents were given a chance to make a final summary comment on the experiences on the 5 to 6 years (to date) of the project. Responses were received from 16 out of a possible 15. One site, which was about to terminate its FCB activities, did not respond and 2 sites provided 2 responses.

All sites reported their FCBs in Regular Operations.  Some sites were also at earlier stages with new orders for buses/HRSs.

The feedback from the sites was compiled and presented and discussed in the regular consortium meetings. Where possible special workshops were held to sum up and validate the information that had been reported and findings derived, as well as gain any additional insights. All consortium members present were able to participate.

As mentioned earlier, some supplementary inputs of information derived from personal approaches, other reporting mechanisms within the two projects and from previous FCB projects have also been included.

# Annex C Quantitative Expectations for Performance

Suppliers and customers of FCBs and HRSs have repeatedly stressed the major benefits of technical specifications being described as expected performance outcomes rather than inputs (see e.g. Section 3.0). This approach leaves it open for the supplier to recommend their best and most cost-effective solution to provide those services. For example, it is recommended to specify a certain amount of hydrogen to be dispensed within the refuelling window (dispensing capacity) and a maximum time to fill per bus, rather than requiring a certain size for the HRS on-site storage (storage capacity).

To help focus JIVE and JIVE 2 project partners on this, and to have them clarify their expectations for performance, the local site coordinators were asked in 2018 to quantify these with respect to a set of parameters.

In late 2023 and based on 2018 responses, the sites still on the projects (10 out of the 17 responding in 2018) were asked whether their expectations were achieved and, regardless of expectations being met, whether they were satisfied with what was achieved. In addition to Yes/No responses, supporting comments could be made.

This Annex provides an aggregated overview of the responses in both rounds.

### Topics covered

- Regarding FBCs:
  1. Availability
  2. Operating costs
  3. Fuel cell stack lifetime
  4. Specific fuel consumption
  5. Acceptable wait time for repairs
- Regarding HRSs:
  6. Availability
  7. Time to fill a bus
  8. Acceptable wait time for repairs
  9. Cost of hydrogen

### Methodology of evaluation

In 2018, the responses were evaluated by calculating:

- ➢ the lowest and highest values

- ➢ the median (the centre value of a dataset that is sorted is ascending or descending order; in case of even set of numbers: the arithmetic mean of the two central two; the median helps eliminate the impact of outliers.
- ➢ the arithmetic mean (not included in the following)

In 2023, the Yes and No answers were counted. Responses that did not express a clear Yes or No (e.g. “Don’t know” or no response or comment given) were categorised as “Other”.

Responses were received from 9 out of 10 of the sites who were surveyed. One site with two HRSs answered in part for each HRS, so the total count amounts to 10 responses in some cases.

## Summary 2018

The expectations of the performance of both the HRSs and the FCBs were high. Even the median values in some cases exceeded the targets defined in the projects’ work programmes. In most cases, the spread between the lowest and highest entries was significant and there were marked outlier values with respect to the highest expectations.

## Summary 2023

Even though the original expectations for performance were not always met, the satisfaction levels with what had been achieved was higher across most of the topics and even much higher with respect to a few topics.

## 1. FCB Availability

| **Responses in 2018** | **Min 80%** | | | **Median 90%** | | | **Max 99.9%** |
|---|---|---|---|---|---|---|---|
| **Expectations Achieved?** | **Y** | **N** | **Other** | | | | |
| **Satisfaction with Achievement?** | | | | | **Y** | **N** | **Other** |
| | **4** | **4** | **1** | | **8** | **0** | **1** |

<u>2018</u>

The expectations ranged from 80% to 99.9%. The median value of 90% was in line with the projects’ target, which was to reach more than 90% after an initial six-month ramp-up phase. The highest expectations of 99.9% did not appear to be reasonable given that only one site in the previous CHIC project (2010 to 2016) achieved the 85%

availability target for that project. Few if any suppliers would guarantee such a level of availability even for diesel buses.

2023

Only about half of the sites saw their expectations achieved. However, all of them were satisfied with the level of FCB availability actually reached.

## 2. FCB operating costs relative to standard fleet

| Responses in 2018 | Min 75% | | Median 150% | | | Max 400% | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 4 | 3 | 2 | | 6 | 2 | 1 |

2018

The JIVE/JIVE 2 target was to achieve 200% or less of the operating costs required to maintain an equivalent a diesel bus, aiming at 150% by the end of the project. The median was in line with this, but some sites expected much better figures.

2023

Again, only about half of the sites saw their expectations achieved, while the level of actual satisfaction was better. One comment expressed that the current high values reflect the cost of innovation.

## 3. Fuel cell stack lifetime

| Responses in 2018 | Min 7,000 hrs | | Median 25,000 hrs | | | Max 50,000 hrs | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 3 | 2 | 4 | | 7 | 1 | 1 |

<u>2018</u>

The JIVE/JIVE 2 target was > 20,000 operating hours. The median expectation was somewhat higher at 25,000 hours.

A few of the stacks in CHIC buses had already surpassed 20,000 operating hours. The manufacturer of a then recently announced fuel cell for heavy duty mobility applications stated a stack lifetime > 30,000 hours.

<u>2023</u>

A third of the sites saw their expectations fulfilled while almost half of them said it was too early to judge (categorised as "Other"). Most sites were content with the development so far.

## 4. Specific fuel consumption

| Responses in 2018 | Min 8 kg | | | Median 9 kg | | Max 12 kg | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 8 | 0 | 1 | | 9 | 0 | 0 |

<u>2018</u>

The median figure of 9 kg/100 km was in line with the target of less than 9 kg/100 km for buses of 12 to 13.5 metres length. The feasibility of the median was supported by the fact that 12 m FCBs in CHIC achieved less than 9 kg/100 km and 13.2 m FCBs with three axles in the HyTransit project (2013 to 2019) 10.7 kg/100 km on average.

<u>2023</u>

Expectations were met almost unanimously, and all sites were happy with their actual specific fuel consumption. The 9 kg/100 km target was undercut at many sites.

### 5. Maximum wait time for repairs of the FCBs

| Responses in 2018 | Min 2 hrs | | Median 24 hrs | | | Max 72 hrs | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 4 | 2 | 3 | | 4 | 3 | 2 |

<u>2018</u>

Wait time for repairs had not been analysed in previous projects, but it was clear that the 24 hours (the expected median value in JIVE/JIVE 2) had not always been achieved. Therefore, achieving 24 hours could be considered challenging, requiring good support from the technology suppliers.

There was no target for JIVE/JIVE 2 concerning wait time in the work programmes of JIVE/JIVE 2.

<u>2023</u>

At about half of the sites their expectations were met, well in line with the level of satisfaction. Comments included that the 'Yes' only applied to minor issues and if there is no requirement to source spare parts.

### 6. HRS Availability

| Responses in 2018 | Min 90% | | Median 99% | | | Max 99.9% | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 3 | 6 | 1 | | 4 | 5 | 1 |

<u>2018</u>

The expectations ranged from 90% to 99.9% with a median value of 99%. The latter was in line with the work programme target (98%, with aspiration to achieve 99%; with time for scheduled preventive maintenance not considered downtime).

HRSs in the CHIC and HyTransit projects had proven that availabilities above 98% are feasible.

<u>2023</u>

Only one third of the sites saw their expectations met. Satisfaction was slightly higher.

Comments included that HRSs have turned out to be the Achilles heel of FCB operations. Another site highlighted that 99% still could mean one out of 100 days without refuelling, meaning no bus service, which is unacceptable. Another site mentioned that they had had issues with the hydrogen supply chain rather than with the HRS as such.

## 7. Time to fill a bus

| Responses in 2018 | Min 5 min | | | Median 10 min | | Max 15 min | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 4 | 4 | 1 | | 9 | 0 | 0 |

<u>2018</u>

The JIVE projects had a target for the speed of dispensing rather than time to fill. The intention was to refuel faster than 3 kg/minute. Assuming a required range of 330 km/day and the target 9 kg/100 km fuel consumption, close to 30 kg hydrogen would have had to be dispensed. At 3 kg/minute this would have taken 10 minutes and be in line with the median expectations of the sites.

In previous projects, 2.8 kg/minute had been the highest average speed achieved across some 1,800 fills.

<u>2023</u>

While expectations were met at only about half the sites, all are satisfied with the performance of their HRSs in this respect.

A comment highlighted that the site’s satisfaction with time to fill was mainly due to the excellent fuel consumption of the buses, requiring smaller fills than expected and resulting in acceptable time to fill.

### 8. Maximum wait time for repairs of the HRS

| Responses in 2018 | Min 0 hrs | | | Median 12 hrs | | Max 120 hrs | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 2 | 5 | 2 | | 4 | 4 | 1 |

<u>2018</u>

As with the FC buses, wait time for repairs had not been analysed in previous projects, and there was not target defined in the work programmes of JIVE/JIVE 2. Meeting the 12 hours median expectation could be considered challenging, requiring very good support from the technology suppliers.

<u>2023</u>

Waiting for HRS repairs was the item with the lowest level of achievement across the sites. Nonetheless, the actual satisfaction once again was notably higher.

As for the bus side, a comment mentioned that minor repairs were quick while major repair work partly takes long.

### 9. Cost of hydrogen

| Responses in 2018 | Min 4 €/kg | | | Median 6 €/kg | | Max 12 €/kg | |
|---|---|---|---|---|---|---|---|
| Expectations Achieved? | Y | N | Other | | | | |
| Satisfaction with Achievement? | | | | | Y | N | Other |
| | 4 | 5 | 0 | | 6 | 2 | 1 |

<u>2018</u>

The median value was 6 €/kg, therefore significantly smaller than the JIVE/ JIVE 2 project target of < 9.0 €/kg hydrogen dispensed (excluding taxes) at the end of the project(s).

The median across the CHIC sites for OPEX alone had been 17 €/kg (target: 10 €/kg), but these HRSs had been highly underutilised. The best OPEX figure for the HRS in HyTransit had been 10.67 €/kg over one calendar year at a rate of utilisation of 51%.

2023

Expectations were met at almost half of the sites, with higher satisfaction levels than actual achievement.

Comments referred to price increases as a consequence of the energy crisis in Europe in the past few years.

### Why the higher satisfaction despite non-achievement of performance expectations?

This question was put to the deployment sites who participated in the re-survey in a conference call. Some were surprised by the finding. The only rationale put forward was that the challenge of less than expected performance in some of the areas was met with 'local' innovative solutions. These solutions led to a general sense personal achievement and that while there were many things that should be improved (particularly on the side of the HRS), the buses actually did work and are a viable, clean option for public transport. This Final Best Practice Report, the culmination as it is of 7 years of data collection from multiple sources, has captured many of those solutions for FCB deployment into the future.

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ERM

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Hydrogen Europe

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