KNOWLEDGE BRIEF

# FUEL CELL BUSES IN YOUR FLEET: A CASE STUDY GUIDE TO BEST PRACTICE IMPLEMENTATION

OCTOBER | 2024

## INTRODUCTION

*This Knowledge Brief offers a case study of how a project to introduce Fuel Cell Buses (FCBs) into an existing bus fleet may look. It draws on best practice information collected over seven years of the JIVE projects[1], based on real-world experiences of the cities shown in the map below.*

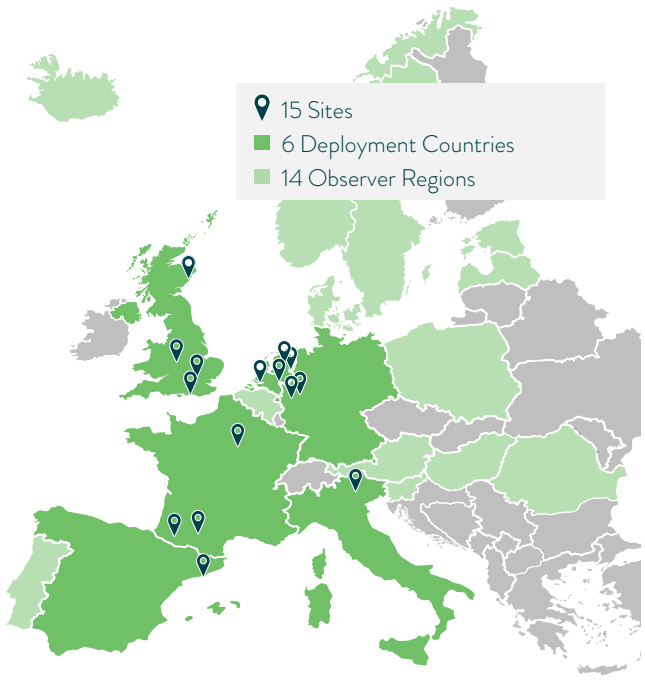


*Figure 1: The JIVE/JIVE 2 deployment sites.[1]*

*When combined, the JIVE & JIVE 2 projects have deployed 290 FCBs throughout Europe. The objective was to demonstrate FCBs as a functional decarbonisation solution for public transport fleets. As of 30 June 2024, these FCBs had driven 20 million km and had been refuelled with 1.5 million kg of hydrogen.*

*It is important to underline that this case study describes an ideal scenario where, due to thorough analysis and planning, the implementation project proceeded relatively smoothly. It serves to highlight approaches that have worked but by no means takes the place of the full Best Practice Report[1] nor the wealth of experience of sites who are operating FC Buses.*

*It is also important to remember that all contexts are different, so the advice provided by this case study needs to be viewed in the light of your own individual project and its specific circumstances. That said, there is valuable advice here for every situation.*

## SETTING THE SCENE

The local council of European City X has decided — given the twin imperatives of improving air quality and meeting EU $CO_2$ emission standards and related policies — that 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 FCBs to achieve decarbonisation goals.

1 The Knowledge Brief is based on the case study and additional material from the JIVE and JIVE2 Best Practice Report 2024

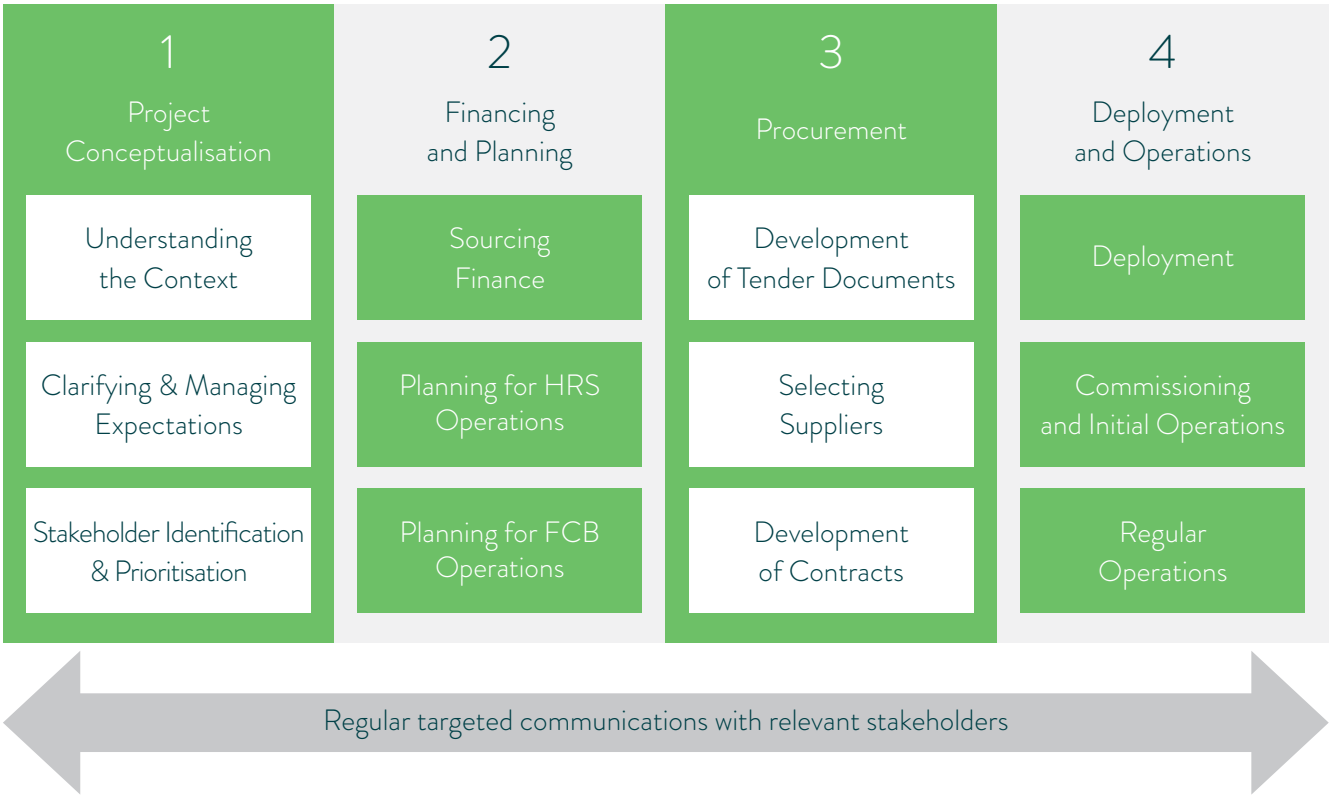


*Figure 2: Stages and sub-stages of a project to implement Fuel Cell Buses and their hydrogen fuel infrastructure.*

Based on best practice work in FCB demonstration projects at different sites across the EU, they decided to follow the 'Stages' approach (see figure above) developed during these earlier activities.

## STAGE 1 – PROJECT CONCEPTUALISATION

The CEO of the Public Transport Authority (PTA) was tasked with making this a reality. An experienced senior manager was appointed project leader (PL) and charged with sourcing funding and implementing a programme to deliver the outcome. The PL established a dedicated project team of three full-time workers. This added a technical person with a good understanding of bus technology, another with knowledge of alternative energy technologies and good networks among the Public Transport Operators (PTOs) active in the city and an expert in the area of tendering and contracts. The team were provided with access to a senior financial officer tasked with supporting the project.

A high-level project steering committee was also established. This consisted of the city mayor, the CEO, COO of the PTA and one of their senior marketing people. The PL asked for, and gained, the committee's commitment to attend regular briefings, particularly during the early months of the project.

### UNDERSTANDING THE CONTEXT/ CLARIFYING & MANAGING EXPECTATIONS

The project team started with developing a vision which set the project within the context of the city's regional and national strategic plans. Examples of the aspects considered included:

- A thorough explanation of the EU and national policy environments that are driving the decision to invest in clean transport technologies.
- The local energy system (stationary and transport) and its readiness to support the supply of hydrogen for this project. Also explored were the opportunities within the current energy system created by a new transport energy vector.
- The potential synergies with local/regional/cross-regional industry. These could include manufacturers and gas suppliers; by-product from chemical plants and pooling hydrogen demand with other consumers to achieve better prices.

The vision was complemented with a description of outcomes/benefits that the new technology could be expected to deliver. Building on the information gathered, the project team developed a readiness assessment for presentation to key decision makers.

## STAKEHOLDER IDENTIFICATION AND PRIORITISATION

In parallel, key community stakeholders and their areas of interest were identified; significant among these were local PTOs.

A stakeholder map[2] was created and kept up-to-date during all stages, and an initial communication plan was developed and implemented.


*Figure 3: FCB at the public HRS in Barcelona, Spain.*

### IMPORTANT TAKEAWAYS:

- **Advantage:** Highly influential political support;

  **Risk:** Political climates can change — quickly and dramatically;

  **Solution:** Make a robust case that appeals across the political landscape and to other key community stakeholders.
- Appoint experienced, dedicated project staff with a good spread of existing experience and skills needed for this project.
- Develop a broader vision for the project.
- Identify stakeholders early, co-opt all the important players — including a spectrum of political actors — and establish a process for regular, targeted stakeholder communication.

## STAGE 2 – FINANCE AND PLANNING

With the vision in place, the project team carried out an in-depth familiarisation with all aspects of the task ahead, including the following:

- **Enhancing their understanding of all aspects of bus operations in their city**, including tender and funding cycles. Also, speaking with interested PTOs on all aspects of the change, including reconfiguration of the bus depot. Selection of a PTO to partner on the project took place during the planning stage.
- Reviewing existing literature on FCB implementation projects.
- **Visiting - with PTO partners - other cities** that had already gone down the route of FCB acquisition. This included gaining an in-depth understanding of the reasons for their chosen refuelling arrangements.
- **Meeting with FCB sellers and suppliers of Hydrogen Refuelling Stations (HRSs) and hydrogen** and conducting a more formal Request For Information (RFI) process. The latter was based on publicly available performance data on the technology and was designed to test draft criteria with potential suppliers.
- **Engaging an expert to develop a list of potential funding sources** in order to cover the additional costs generated by the new technology.
- Having those responsible for marketing and communications develop a targeted and detailed communication plan and begin awareness raising among the general public.
- **Researching and understanding the impact of permitting requirements** for FCB and HRS deployment at the local site.

This information was fed back to the project steering committee in the regular briefings. Based on research undertaken, the project team drew up the broad outline of an implementation plan that detailed the:

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

### FURTHER IMPORTANT TAKEAWAYS:

- Spread the information-gathering net sufficiently broadly. Importantly, it should include suppliers and cities with existing experience; potentially use a RFI process.
- Speak to PTOs early in order to provide them with information and to understand their perspectives. Once the FCB operator has been selected, involve them directly with scoping out their requirements.
- Work specifically on finding potential additional funding sources.
- Maintain political and community support by attending to issues/concerns raised.

2 See JIVE and JIVE 2 Best Practice Report 2024, p.34

Work had also commenced concurrently on the FCB business plan. This was developed using conservative estimates for costs and — where costs were uncertain — assumed the upper end of the range. This was to reduce any risk of budget 'surprises' at a later date.

FCBs were compared with battery electric buses as zero-emission options. The intention was to make a thorough case for FCBs over the long term, on the grounds of costs, benefits and operational requirements for the bus routes. This included flexibility, grid capability and synergies with other regional hydrogen use options.

The business case time horizon was built around the typical 10 - 15 years replacement cycle for diesel buses. The business case covered CAPEX and OPEX, including 'beyond project' costs that would be expected to arise after a co-funded initial phase.

## CALCULATING THE ADDITIONAL COSTS

CAPEX: Assume higher costs for both FCB and HRS in the medium term.

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

## COVERING THE ADDITIONAL COSTS

Following cost calculations and the funding research being finalised, proposals were submitted to cover the higher CAPEX and OPEX 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.


*Figure 4: Buses and HRS in Aberdeen, United Kingdom. Top: Part of the double-deck FCB fleet. Bottom: Bus refuelling.*

### FURTHER IMPORTANT TAKEAWAYS:

- Continue to seek support from other experienced PTO/PTAs.
- Ensure conservative cost estimates, address additional funding requirements and the need to de-risk in order to achieve PTO buy-in.
- When seeking funding for additional costs, be aware that requirements from funding sources can conflict.
- Plan for going over budget and over time.
- Respond to short deadlines (e.g. to meet co-funding requirements) by running concurrent activities.

## STAGE 3 – PROCUREMENT

**FCB and HRS tenders were dealt with concurrently but separately.** Expert groups were formed, with membership specific to the technology. One expert group (drawn mainly from the PTA) would manage the HRS tender, while 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 seek both FCBs and HRS being commissioned simultaneously, but was also consistent with the investment cycle of PTA/PTOs, to take advantage of existing and proven procurement processes and to work within the city's budgeting arrangements.

**Early professional safety assessments for the HRS and the bus maintenance facility were arranged and the outcomes fed into the tender documents.** To allay fears, these outcomes were also shared with local authorities and first responders and permitting documentation commenced.

## DEVELOPING TENDER DOCUMENTS FOR THE HRS AND HYDROGEN SUPPLY

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

The tender document emphasised desired performance outcomes, rather than specifying inputs. These included:

- requirements for **dispensing capacity** during a daily refuelling window of some hours (rather than the size of the hydrogen **storage**)
- modularity and scalability
- availability and reliability metrics

- precision of hydrogen metering and hydrogen quality assurance (purity)
- penalty measures.

**Regular and backup hydrogen supply was also put out to tender.**

Tenderers were strongly encouraged to visit the proposed HRS location and to speak to FCB manufacturers to understand their current technology (for example, bus-to-HRS communication).

## DEVELOPING TENDER DOCUMENTS FOR THE FCBS

As the PTO was in the process of purchasing new buses, the procurement of FCBs was added into their normal tendering arrangement.

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 hydrogen drive train components already tested through an RFI in the planning stage. A key performance criterion is fuel consumption.

## SELECTING SUPPLIERS / DEVELOPMENT OF CONTRACTS

Prices offered for the HRS proved higher than had been hoped for. The final price was negotiated with the preferred supplier during the contracting process. Issues over ownership, responsibilities, operational data to be logged and provided, guarantees and warranties, penalties and the coverage of third-party suppliers (such as the manufacturer of the hydrogen compressors, being key/critical components) were all addressed when developing the contract. On the hydrogen supply, the PTA was able to offer a guaranteed length of contract with break clauses.

### FURTHER IMPORTANT TAKEAWAYS:

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

# STAGE 4 – DEPLOYMENT & OPERATIONS

## DEPLOYMENT

Once the procurement contracts were signed, the team turned its focus to the preparation required before FCB operations could commence. A timeline for delivery of the buses and the availability of refuelling had been agreed as part of the contracts. A buffer was built into the timelines to manage any delays and also to ensure that stakeholder expectations were realistic.

The HRS was contracted to come online ahead of the buses, to allow for refuelling and testing the first buses upon receipt.

### 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 within the timeframe acceptable to the PTO. The HRS also allowed for the possibility of scaling up the number of buses used and for refuelling other types of fuel cell vehicles at different pressures.

### Bus Depot

Adapting the bus depot was a major concern for the PTO. This required upgrading the workshop, upskilling the staff and reconfiguring the parking space, with special attention paid to safety requirements. This in turn required effective planning and design to ensure that the run-in, refuelling and/or charging, parking, maintenance and run-out processes were compatible and optimised for all bus types. There was consideration for further expansion of the fleet, including other zero-emission options. The PTO had received a grant for this extra work and controlled the contracts to make it happen.

### Route Checking

The PTO had already identified the designated routes for their new buses. These were to be heavy-cycle routes suited to FCBs with their range and flexibility. Two buses were to be assigned to the 'Clean Air' zone in the heart of the city to give the new technology high visibility. Meticulous checking of these routes now commenced in order to identify any previously unforeseen hazards for the somewhat taller (fuel cell equipment on the roof) and heavier buses. This check would be repeated immediately prior to the buses entering operation as well as being emphasised in driver training. This included potential bus diversion routes.

### Awareness Raising and Training

The PTO and the PTA also worked together to schedule awareness raising and targeted training for all the various groups 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
- the general public.

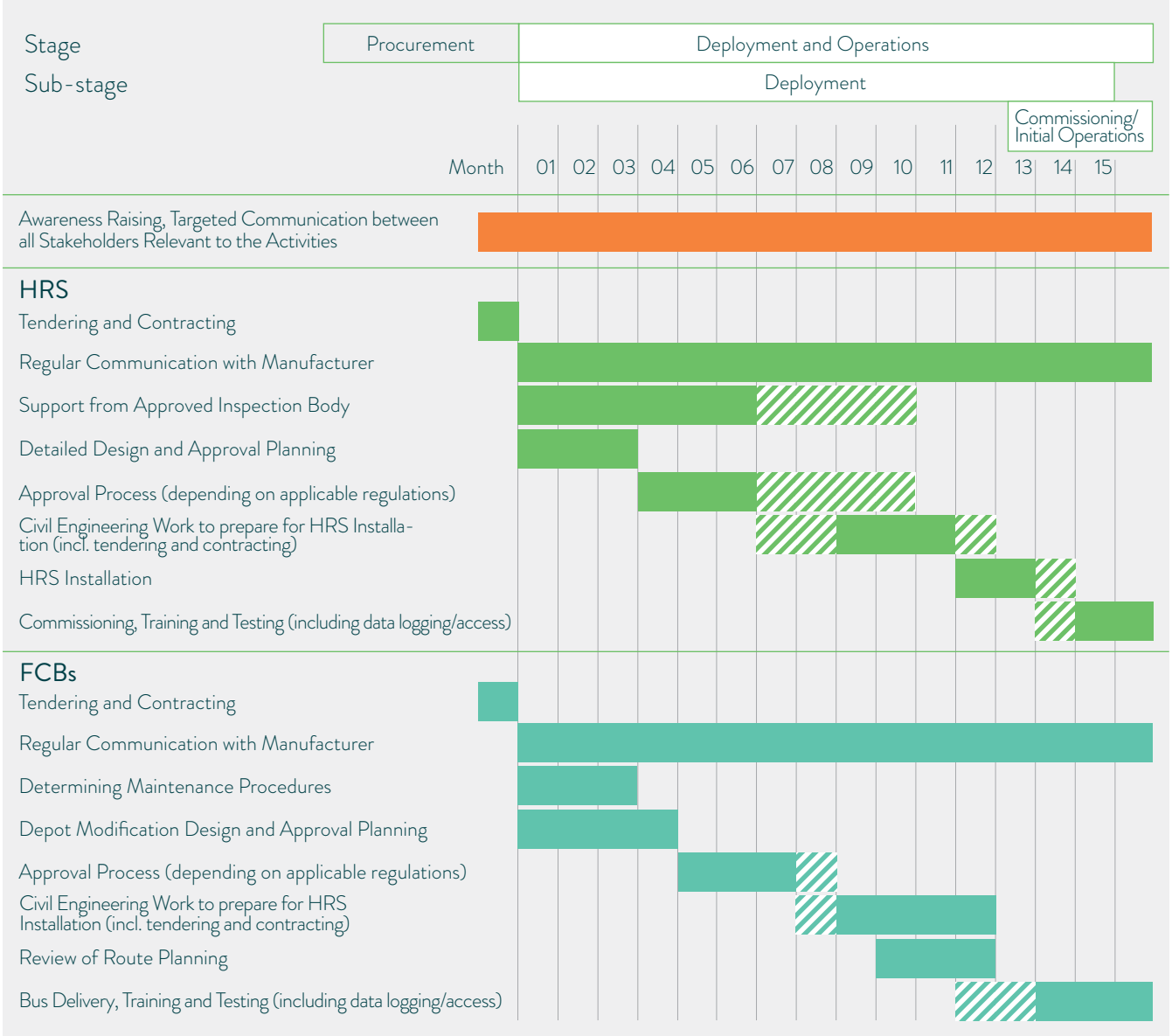


*Figure 5: Indicative timescale for the deployment sub-stage. Striped periods indicate possible extra time needed or potential for an earlier start. Based on a chart developed by Regionalverkehr Köln and expanded with their support.*

As part of the contract, the bus supplier had agreed to a 'Train the Trainer' arrangement, where initial instruction was undertaken by the supplier and gradually taken over by the PTO. Full documentation would be provided to the local trainers, and — as part of the contract — a staff member of the bus supplier would remain available for a further year as support for the local people. The same approach was taken with personnel working at the HRS.

The groundwork for obtaining permits for the new facilities had been laid as part of the communications strategy at the planning stage. Activities in this area now accelerated, with support from the FCB and HRS suppliers.

## COMMISSIONING AND INITIAL OPERATIONS

Despite best efforts 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 in order to meet specified availability metrics. These were activated to coincide with the arrival of the first FCBs.

### 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. Route suitability was thoroughly tested and a note made for driver training that the FCBs were not to be run on unauthorised routes. Some standard components were found to be faulty; this was 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 those 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 undertaken, involving the city's first responders and relevant depot staff including drivers.

Onboard data collection and delivery systems specified by the contract were tested and found to be fit for purpose. The bus and HRS supplier were contractually obliged to resolve any inconsistencies in readouts and co-operate in this respect, and both were able to successfully achieve this to meet the needs of the PTO.

### HRS Commissioning and Testing

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

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

Refuelling times were verified and found to be adequate with pre-cooling in place. However, HRS data was not forthcoming as per the contract due to software errors. This was resolved, and there was no need to invoke penalty clauses ahead of regular operations.

## REGULAR OPERATIONS

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

Performance of the HRS proved poorer than expected. It experienced numerous shutdowns during the first six months of operations. These events were greatly mitigated by the contractual backup hydrogen delivery and storage service. Having invested in a hydrogen trailer facility, the site was able to use it as a mobile refueller.

An unexpected rise in electricity prices led to a significant increase in the per kilogram cost of hydrogen. This triggered the agreement for the PTA to cover a price rise above an agreed amount in order to derisk this aspect of the OPEX to the PTO.

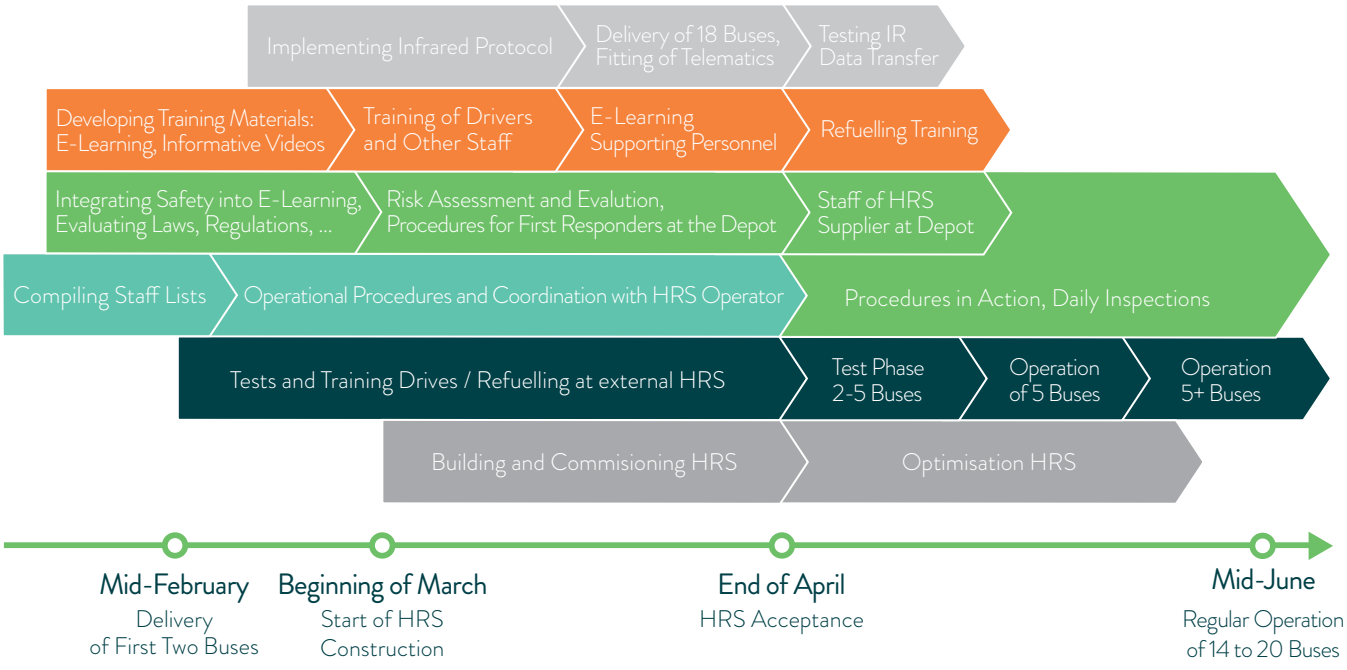


*Figure 6: Staff Training in Context: Sample Plan. Based on a chart developed by Qbuzz with their permission. Qbuzz operate FCBs in the Dutch provinces of Groningen and Drenthe. Timelines are indicative and will depend on local conditions.*


*Figure 7: HRS with on-site hydrogen generation in Pau, France. An H2 production and storage facility is shown at the left of photo. Buses are sequentially refuelled overnight at their parking bays. The high level of redundancy in terms of dispensers at this site is exceptional.*

## FURTHER IMPORTANT TAKEAWAYS:

- The rapport built up with suppliers both on the bus and the refuelling sides will be invaluable once regular operations commence. Relations between bus and refuelling contractors should be facilitated as part of good communication between all parties.
- Rigorous planning (including contingency planning) and contractual comprehensiveness will avoid or mitigate most of the routine challenges experienced in the deployment and operations stage.
- Unexpected challenges will become easier to handle by introducing a buffer into your timeline and your budget for regular operations. Expect delays and increases in costs.
- Have backups in place, both for the buses and for the HRS. While buses are extremely reliable by new technology standards, both they and the HRS will experience teething problems.
- Good training and maintenance = SAFE operations
- Leverage the introduction of the buses to demonstrate to the public that you will be meeting European emission standards. It will become a source of pride for the municipality and region and encourage public transport use.

## THE MOST IMPORTANT LESSON TO BE LEARNT FROM THIS CASE STUDY

From the moment that contracts are signed, and throughout all the sub-stages of Stage 4, maintaining continual communications with the FCB supplier, the HRS supplier and the hydrogen fuel supplier is essential. It is equally important to facilitate an ongoing dialogue between all suppliers.

Once the buses and infrastructure are in place, it is then far too late to find out that they will not interface efficiently and effectively. Worse still is to discover that no supplier is willing to take responsibility for that breakdown, each pointing the finger at the other.

FCBs and their infrastructure represent a paradigm shift. However, the experience of the JIVE and JIVE 2 deployment sites, distilled within this case study, should help others avoid the common pitfalls and to experience a smoother passage into the decarbonised public transport system of the future.

This Knowledge Brief is based on the JIVE/JIVE 2 Best Practice Report developed by Klaus Stolzenburg (PLANET GbR Engineering and Consulting), Nicole & Simon Whitehouse (Sphera Solutions GmbH).

This is an official Knowledge Brief of UITP, the International Association of Public Transport. UITP has more than 1,900 member companies in 100 countries throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

Acknowledgments:
The JIVE and JIVE 2 projects have received funding from the Clean Hydrogen Partnership Joint Undertaking under grant agreement No 735582 and 779563. This Clean Hydrogen Partnership receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe Research. UITP contributed to the review of this brief as well as carried out the editorial work and publishing.

Authors and contacts for the BestPractice Report and Case Study:

Klaus Stolzenburg, PLANET GbR Engineering and Consulting.
k.stolzenburg@planet-energie.de (JIVE)

Nicole Whitehouse, Sphera Solutions GmbH.
NWhitehouse@sphera.com (JIVE 2)

Simon Whitehouse, Sphera Solutions GmbH.
SWhitehouse@sphera.com (JIVE 2)

JIVE and JIVE 2 project contacts:

Magali Senaux, Project Coordinator. ERM
magali.senaux@erm.com

Flavio Grazian, Project Dissemination. UITP
flavio.grazian@uitp.org