Implementing FC Buses: A Summarising Case Study (2024)

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.

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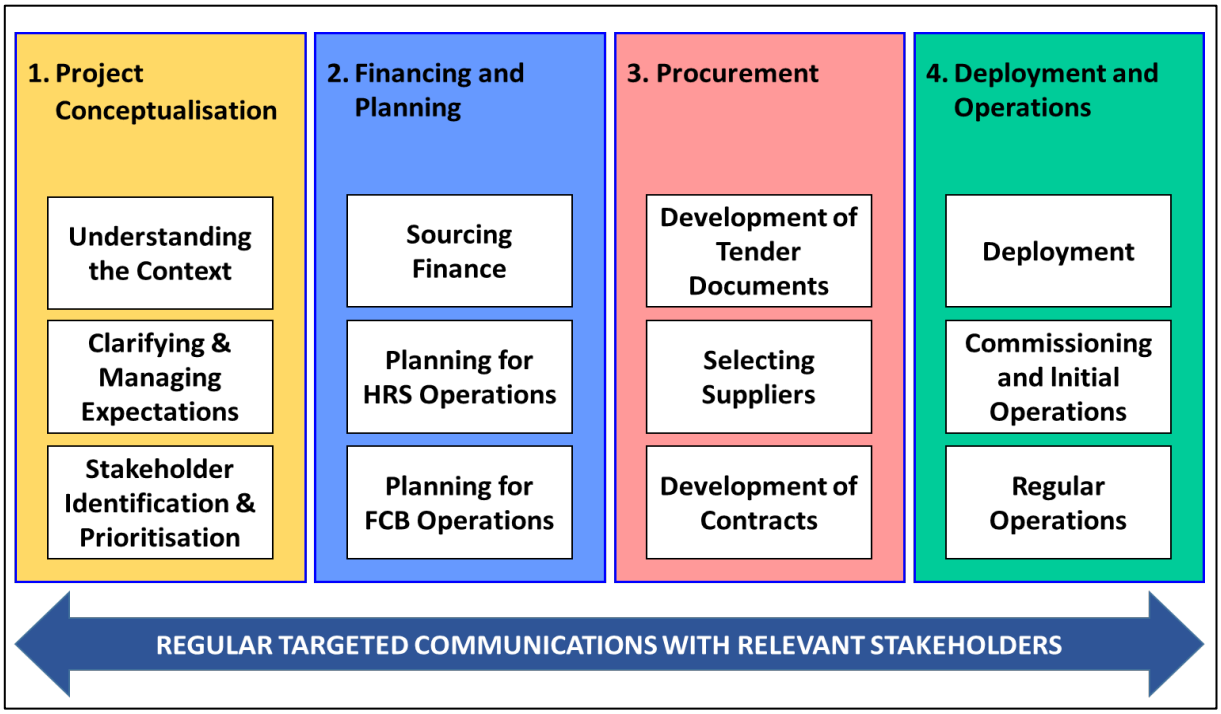

Stages and sub-stages of a project to demonstrate Fuel Cell Buses and their hydrogen fuel infrastructure.

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 took place 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.

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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.