ADVANCING PUBLIC TRANSPORT

ZERO EMISSION

KNOWLEDGE BRIEF

FUEL CELL BUSES:
BEST PRACTICES AND COMMERCIALISATION APPROACHES

JULY | 2020

INTRODUCTION

With the increasing pressure on city authorities to work towards the Paris Agreement goals and tackle air pollution, fuel cell buses (FCBs) are one of the few zero emission transport solutions. Under development for some years and gaining traction ever since, due to the short refuelling times and long range of the vehicles, FCBs are a viable option for decarbonising public transport networks.

The Joint Initiative for hydrogen Vehicles across Europe programme, known as the JIVE and JIVE 2 projects, in conjunction with the MEHRLIN project, are funded by the EU and are introducing new fleets of FCBs and associated hydrogen refuelling infrastructure in cities and regions across Europe. UITP is a partner in these projects.

This Knowledge Brief reproduces a fictional case study[1] from the ***JIVE and JIVE 2 Best Practice Report 2020*** *which provides an account of how a new adopter might go about integrating a fleet of FCBs. The aim of this brief is to give readers a better understanding of the process, using a walk-through approach from start to finish and identifying best practices along the way. For more factual and technological information, you can check out the full project report[2].*

ABOUT JIVE AND JIVE 2

The underlying objective of the JIVE and JIVE 2 projects is to support the transition of FCBs to becoming a more mainstream choice for public transport authorities and operators across Europe. Therefore, the JIVE and JIVE 2 projects focus on preparing the market for wider scale roll-out of FCBs. This will involve addressing several outstanding challenges for the sector, such as reducing vehicle ownership costs, increasing the choice of hydrogen fuel cell bus models and proving the feasibility of operating large fleets of fuel cell buses.

As the next phase in the FCB transition, the JIVE and JIVE 2 projects will deploy around 290 new buses which will be operated for extended periods in standard commercial

1 The case study, while fictional, does draw on a range of real life scenarios from the JIVE and JIVE 2 Projects • 2 The full report is available here: https://fuelcellbuses.eu/publications

operations at numerous, different sites. The overall vision is to pave the way for full commercialisation of fuel cell buses in Europe in the 2020s by sharing information and stimulating further uptake. In the JIVE and JIVE 2 projects the local fleets range from five to 50 FCBs, typically 10 to 20. Some of the Hydrogen Refuelling Stations (HRSs) are implemented and operated within the MEHRLIN project, which is funded under the Connecting Europe Facility (CEF) for Transport.

Deployment sites in JIVE and JIVE 2, as of July 2020

JIVE buses | JIVE 2 buses | MEHRLIN HRS* | *Hydrogen Refuelling Station

WHERE BUSES WILL BE DEPLOYED

The table below shows planned deployments of FCBs in the JIVE and JIVE 2 projects.

CITY/REGION	Total number of buses
Aberdeen, UK	21
Auxerre, France	5
Barcelona, Spain	8
Birmingham, UK	20
Brighton, UK	22
Charleroi, Belgium	10
Cologne, Germany	50
Dundee, UK	12
Emmen, The Netherlands	10
Gelderland, The Netherlands	10
Groningen, The Netherlands	20
London, UK	20
Pau, France	5
Rhein Main, Germany	10
South Holland, The Netherlands	20
South Tyrol, Italy	12
Toulouse, France	5
Velenje, Slovenia	6
Wuppertal, Germany	20

* Four buses remain under review

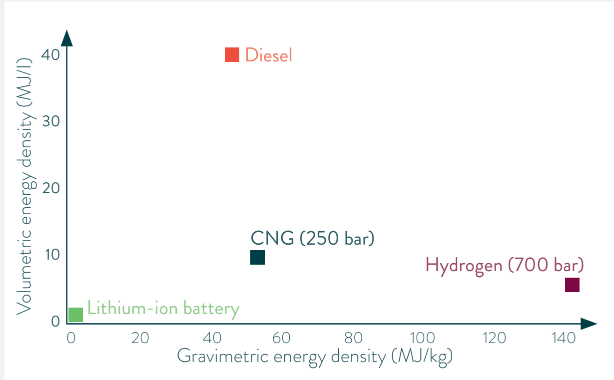
Van Hool buses deployed in Pau, France

WHAT IS A FUEL CELL BUS?

A fuel cell bus (FCB) is an electric bus that includes both a fuel cell and a battery (or in some cases supercapacitors). This hybrid architecture uses the fuel cell to supply most of the energy for vehicle operation, whilst the battery provides support during peak power demands such as for rapid acceleration and gradients. The fuel cell consumes hydrogen to generate electrical energy through an electro-chemical reaction, leaving only water and heat as by-products. The electrical energy is used to power electric motors and keep the battery charged. The by-product heat can be used for cabin heating, thereby maintaining passenger comfort while improving vehicle efficiency. The battery also provides storage for energy regenerated during braking.

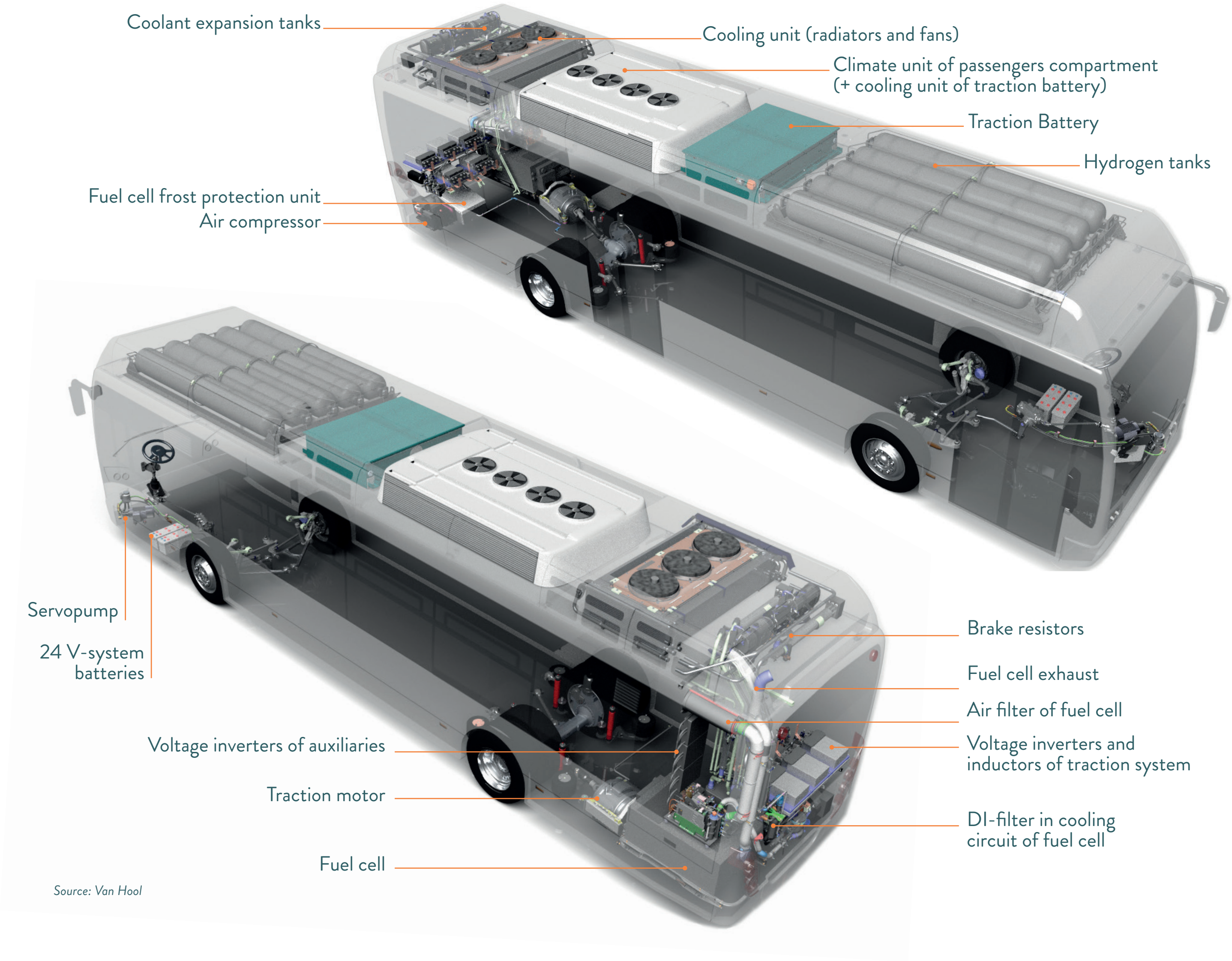
Hydrogen offers a much higher energy density and at lower weight compared to current electrical storage systems such as batteries. A FCB can operate for an entire day of service without refuelling. All the energy required for the bus to operate is provided by hydrogen stored on board.

Illustration of hydrogen's high energy density compared to other technologies



© UITP

The illustrations below show an example of how major components can be arranged on a FCB, courtesy of Van Hool. Other bus manufacturers put the fuel cell on the roof and the traction battery can also be located at the rear, for example.



Source: Van Hool

CAPTURING CHALLENGES AND BEST PRACTICE SOLUTIONS

The monitoring and analysis activities of the JIVE projects include capturing challenges encountered and best practice solutions. The objective of this activity is to document the learning that has and is occurring in these and previous projects, primarily for the benefit of new users of the technology.

This knowledge brief presents the summary case study from the full best practice report. As the JIVE projects are on-going, the case study covers the process of installing FCBs up to and including the procurement of the FCBs and Hydrogen Refuelling Stations (HRSs).

SETTING UP A FUEL CELL BUS PROJECT: A CASE STUDY IN BEST PRACTICE

The case study scenario is based on a range of 'real-world' examples and on the experience of the authors. It brings together in a narrative many of the key best practice recommendations gathered from JIVE and JIVE 2 project partners and other experts. This is an 'ideal' scenario and should be interpreted as such, serving only as an illustration to highlight approaches that work.

It is important to keep in mind that the advice that you find in this case study and in other resources needs to be considered in the light of your own project and its specific circumstances. Having said that, there is relevant advice here for every situation.

THE CONTEXT

The year is 2020 and in European City X the local administration has issued a regulation that improving air quality was the highest priority and that public transport buses would need to move to emission free alternatives from 2024 onwards. Because of the currently limited range of battery electric buses (BEBs), the local administration decided to acquire FCBs. These decisions had strong and widespread political and community support.

1. PROJECT CONCEPTUALISATION STAGE

The Mayor of the city, a highly respected former national politician with deep political networks, 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 public transport operators (PTOs) 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, 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 in the early months of the project.

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 energy, the relevance to local industry[3] and to national and supranational requirements to meet clean air and climate change targets. Examples of what was considered included:

- A thorough assessment and 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 energy might be leveraged in this setting (e.g. H_2 as a buffer for intermittent renewable energy).
- The opportunities to create synergies with local/regional/cross-regional industry (manufacturers, gas suppliers, by-product H_2 from chemical plants etc).

3 This would include industries such as a hydrogen bus original equipment manufacturers (OEMs) as well as broader industry such as chemical industries that create H2 as a by-product; high tech industries that might be interested in tank and fuel cell components etc.

The developed vision 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 was a local PTO who showed interest in being part of the project.

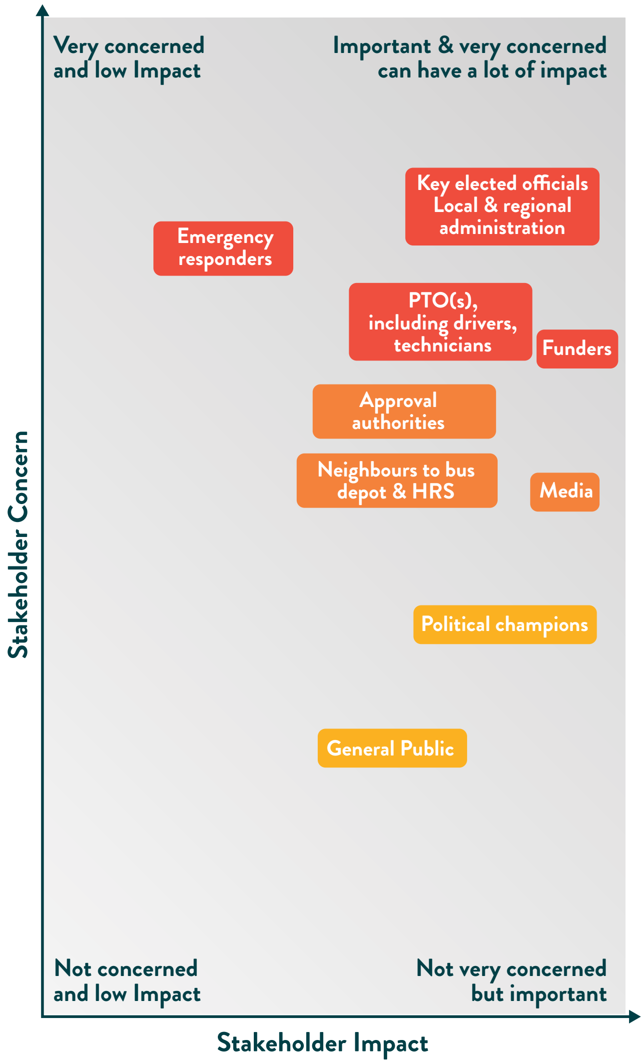
A stakeholder map was drafted and updated during the following stages, and a first communication plan was developed and implemented.

IMPORTANT POINTS FROM THE STORY:

1. Political context:
   - **Advantage:** Highly influential political support.
   - **Risk:** Political climates can change quickly and dramatically.
   - **Solution:** Develop a robust case for FCBs 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 and establish a mechanism for regular stakeholder communication.

Project stages and sample stakeholders identification map

Sample stakeholder criticality chart[4]



2. FINANCING AND PLANNING STAGE

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 dialogue with the PTO, that had volunteered to be the FCB operator for the project[5].
- Reviewing reports from past and ongoing FCB demonstration projects.
- Visiting other cities that had already gone down the route of FCB acquisition.
- 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[6].
- 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 for funding.
- Tasking marketing and 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 and issues raised by the Steering Committee were rigorously addressed.

IMPORTANT POINTS FROM THE STORY:

5. Gather information from a wide variety of sources, importantly include suppliers and experienced cities, potentially use a RFI process.
6. Speak to PTO early to provide them with information and to understand their perspectives, 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.

• 4 It is important to note that the relevance and criticality of the individual stakeholder groups varies from site to site. • 5 This model can vary across cities and countries depending on how the public transport market is structured and organised. For example, there are cases where buses are operated by the local public transport authority, municipality or through the contracting of private operators. For more information please visit the full Best Practice report at *www.fuelcellbuses.eu/publications*. • 6 Another approach is tapping into 'Industry Market Place' forums which includes FCB technology. These are organised by *Clean Bus Europe Platform*. Contact the platform if you are interested in joining to benefit from such activities.

Work 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.

The Project Team understood that covering the likely additional costs of the new technology when compared with diesel buses was essential to getting buy-in from the PTO. As a commercial enterprise, the PTO would be looking to de-risk the process of moving away from what they know and would expect support from the PTA to do so. This de-risking process included an assured H_2 fuel supply.

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 capital expenditure (CAPEX) and operating expenditure (OPEX), including 'beyond project' costs to be expected to arise after the co-funded demonstration phase. It provided comparative cases with diesel, diesel electric and battery electric buses.

Calculating the additional costs

CAPEX: The relative lack of competition among FCB and HRS suppliers, and therefore likely higher costs, was factored into the cost estimation decision process.

OPEX: The volume of H_2 required was to be augmented by assuming conversion of city administration's car fleet to fuel cell vehicles which could assist in securing a lower price for the H_2 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 operations (TCO)[7]) 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. 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, in terms of a Life-Cycle costing approach. 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.

• 7 Read more about TCO in Section 2.1 of the full *Best Practice report*

IMPORTANT POINTS 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.
12. Plan for going over budget and over time.
13. Consider undertaking a Life Cycle Costing exercise.
14. Respond to short deadlines by running concurrent activities.

3. PROCUREMENT STAGE

HRS and FCB tenders were dealt with 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. 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[8].

Developing the hydrogen refuelling station tender

The HRS tender, including H_2 supply, was managed 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 consultation with the PTO.

The tender document emphasised outcomes wanted rather than specifying inputs. Requirements for daily dispensing capacity, modularity and scalability, precision of H_2 metering, H_2 quality (purity), backup supply, and Green H_2 supply in the short to medium term were addressed. Potential suppliers were encouraged to be innovative and given thorough briefings consistent with procurement regulations.

Tenderers were strongly encouraged to talk to vehicle suppliers and to visit the proposed HRS location[9].

Developing the fuel cell bus tender

The PTO was in the process of purchasing new buses and the procurement of FCBs was added into their normal tendering arrangement. However, they indicated that they could have purchased the FCBs as a specific, one off tender arrangement 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[10].

© Van Hool

● 8 A brief overview on safety issues is provided in *JIVE 2 deliverable* ● 9 HRS manufacturers have developed proprietary solutions to optimise the speed of medium and heavy duty hydrogen dispensing. Standardisation for such fills over 10kg is ongoing. The PRHYDE project addresses the current and future developments needed for refuelling medium and heavy duty hydrogen vehicles. It started in January 2020 and will run till end of 2021, see *https://prhyde.eu/* ● 10 For more information, see UITP *Bus tender structure report*

Hydrogen refuelling structure facility in Pau, France

Selecting & Contracting Suppliers

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 H_2 supply, the PTA was able to offer a guaranteed length of contract with break clauses. Issues to do with ownership, responsibilities, guarantees & warranties and the coverage of 3rd party suppliers were all addressed in the development of the contract. The PTA guaranteed the PTO a H_2 fuel price resulting in fuel costs per kilometre driven that were equivalent to using diesel.

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.

IMPORTANT POINTS 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.

19. An early professional safety assessment of HRS and bus maintenance facility provides comfort to local authorities and supports the tenderers.

Stages and Sub-stages of a project to demonstrate FCBs and their hydrogen fuel infrastructure

1 PROJECT CONCEPTUALISATION
Understanding the Context
Clarifying & Managing Expectations
Stakeholder Identification Prioritisation

2 FINANCING AND PLANNING
Sourcing Finance
Planning for HRS Operations
Planning for FCB Operation

3 PROCUREMENT
Development of Tender Documents
Selecting Suppliers
Development of Contracts

4 DEPLOYMENT AND OPERATIONS
Construction
Commissioning and Initial Operations
Regular Operations

5 NEXT STEEPS TOWARDS FULLY COMMERCIAL OPERATION

REGULAR TARGETED COMMUNICATIONS WITH RELEVANT STAKEHOLDERS

CONCLUSION

This is where this 'ideal' FCB acquisition story ends for now. The stage of deployment and operations will be addressed in the future, based on the experiences of the JIVE and JIVE 2 projects sites as their FCBs become operational.

Authors and contacts for the Best Practice 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: Madeline Ojakovoh, Project Coordinator. Element Energy. Madeline.Ojakovoh@element-energy.co.uk ● Efe Usanmaz, Project Dissemination. UITP. efe.usanmaz@uitp.org ● Sabrine Skiker, Project Dissemination. Hydrogen Europe. S.Skiker@hydrogeneurope.eu

Acknowledgments

The JIVE and JIVE 2 projects have received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) under grant agreement No 735582 and 779563. This Joint Undertaking 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. This brief is also available in German, French, Spanish, Italian, Polish, Hungarian, Danish and Portuguese.

Disclaimer

The report reflects only the authors' views and not necessarily the views of UITP or the FCH 2 JU. The FCH 2 JU and the European Union are not liable for any use that may be made of the information contained herein.

This is an official Knowledge Brief of UITP, the International Association of Public Transport. UITP has more than 1,800 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.

DIGITAL VERSION AVAILABLE ON MYLIBRARY

ADVANCING PUBLIC TRANSPORT

Rue Sainte-Marie 6, B-1080 Brussels, Belgium | Tel +32 (0)2 673 61 00 | Fax +32 (0)2 660 10 72 | info@uitp.org | www.uitp.org