JIVE Third Best Practice and Commercialisation Report (D3.25)
JIVE 2 Second Best Practice Information Bank Report (D3.8)

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ZERO EMISSION

JIVEs / MEHRLIN projects

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Clean Hydrogen Partnership

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Executive Summary

The Fuel Cell and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) has provided funding to the JIVE and JIVE 2 projects to support the deployment and commercialisation of Fuel Cell Buses (FCBs) across Europe. Both projects have similar objectives and are following similar project trajectories. They are also encountering similar challenges and solutions.

Capturing Challenges and Best Practice Solutions

The monitoring and analysis activities of the projects include capturing Challenges and Best Practice solutions. This document constitutes the third Best Practice Report under JIVE and the second under JIVE 2, and reports on the activities from both projects which have been brought together and are being run collaboratively. It documents, primarily for the benefit of new users of the technology, the learning that has occurred up to and including the deployment and early operations of the FCBs and Hydrogen Refuelling Stations (HRSs). It aims to be concise, presenting most of the information in tables, supported by introductory and explanatory text.

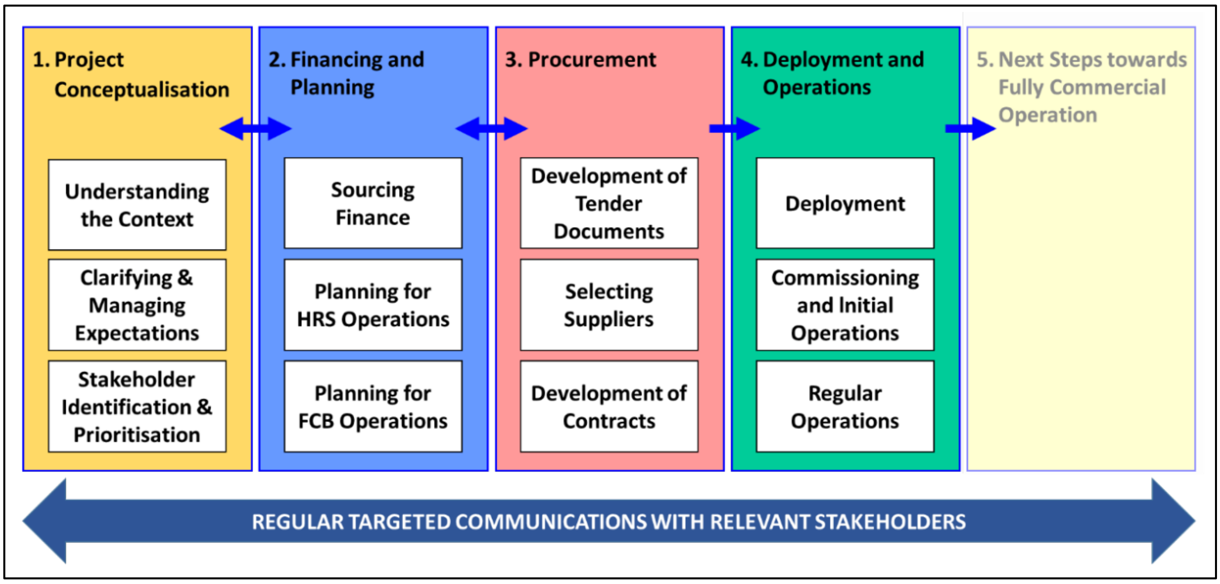
Information Gathering and Processing Method

The local coordinators of the demonstration cities and regions are regularly requested to provide input on their project progress, successes, challenges encountered and solutions found. This input has been supplemented by interviews with some of the local coordinators along with a number of site visits to gain additional on the ground insights, and other input from relevant sources.

The feedback from the sites is compiled, 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.

Project Stages

The project development and implementation process is being considered in 5 major stages as shown in the chart below. In step with the progress of the JIVE projects to date, this document focusses on key issues relating to the first three of these stages: Project Conceptualisation, Financing and Planning, Procurement and Deployment and early Operations. Information is provided for each stage, plus references on further resources that have been of use for the JIVE/JIVE2 sites or in earlier demonstration activities.



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

Stage 1 – Project Conceptualisation

Establishing the overall concept of a FCB project sets the scope and, in many ways, the basis for the overall success of the project. It can also facilitate a broader framework within which other applications of hydrogen and fuel cell technology can be developed and utilised.

Two key factors stand out in identifying those FCB projects which are more likely to both be, and be perceived to be, successful:

- Projects which have been established within a broad context provide the community, including industry, with an understanding of the role that hydrogen and fuel cells can play in the clean energy, environmental and economic objectives of the community. Clean vehicles can be an effective pathway to achieving other goals.

- Establishing and communicating realistic project expectations is also key.

Identifying the key stakeholders and understanding their issues is vital. Not all stakeholders will have the same level of potential positive or negative impact on the project. Prioritisation can be done by mapping them on a matrix with respect to concern and impact/importance. A Communication Plan for engaging with the stakeholders in a targeted manner needs to be established and implemented early.

Committing time and resources to this foundational stage of the project is essential. Getting to understand the benefits and limitations of the technology, building a knowledgeable and committed project team, identifying and connecting with key stakeholders, and networking with other FCB project groups and individual experts are all part of laying a strong and enduring foundation for the project.

Stage 2 – Financing and Planning: Co-Funding to Cover the Additional Costs

Getting the money for the project and starting planning are the next tasks. It is highly likely that some source of grant funds will be needed to cover the additional costs of acquiring and operating FCBs and HRSs over and above the costs of buying and operating Battery Electric Buses (BEBs), conventional diesel or natural gas buses. To encourage Public Transport Operators (PTOs) to embrace the new technology, it is still necessary to de-risk FCB acquisition from a commercial point of view.

No JIVE/JIVE 2 site, including those with experience from previous projects, has found this trouble free, with no obvious patterns that could lead to success or problems. Much seems to depend on specific knowledge of local, regional and national funding programmes, and local circumstances at the time, particularly political support. The existence of EU and national targets for emission reduction and clean vehicles have provided strong incentives. In addition, seed funding through various programmes (in particular the Clean Hydrogen Partnership) has been crucial. More recently some private investment options have also arisen in some countries.

To establish the additional costs currently resulting from operating FCBs requires precise estimates of all elements of the Total Cost of Ownership (TCO). This includes the investment and all operations-related direct and indirect cost elements, as well as 'beyond project' items arising after the co-funded phase up to the vehicles' end of life. Deciding on which bus type to use as the base case for comparison is important as well (e.g. diesel or battery electric).

While TCO calculations typically do not include the external impacts of operating conventional buses, such as health and environment, these costs are clearly increasingly relevant and significant. Estimating these externalities in the context of Life-Cycle Costing, that is the external costs avoided through operating zero emissions buses, can provide a useful argument when negotiating for additional funds or, in the future, cheaper loans from government for whom these external costs are a large budget item.

Stage 2 – Financing and Planning: Planning for Operations

The operational stage is the most important aspect of a FCB project. It will be the most public activity of the project and therefore most open to scrutiny. The key to achieving successful operation is comprehensive and meticulous planning.

General Best Practice solutions, applicable to both HRS and FCBs, include:

- Specifying for local needs, in line with the specific local/regional broader framework ('vision') that has been developed
- Visiting and talking to experienced sites and potential suppliers
- Engaging early, often and widely; planning for clear and consistent communication with the stakeholder groups identified and in line with their needs (including e.g. bus drivers, maintenance staff, entities providing funding, ...)
- Having clear and specific responsibilities, boundaries and accountabilities among the local project partnership which can include the suppliers
- Be open to reason as everyone is still learning

There is a large amount of written information and both formal and informal learning among experienced cities that can and should be accessed to assist with this planning – most of which is either included or referenced in this resource. These will provide excellent guidance and help avoid repeating previous mistakes. The other critical issue is to adequately resource this stage of the process – particularly in terms of personnel expertise and time set aside for the planning process. Plan to set up a broadly-based tender team.

Stage 3 – Procurement

The procurement of FCBs and HRSs is considered from the point of view of developing the tenders, selecting the suppliers and developing the contracts. While the general steps and processes are well known, the procurement of FCBs and HRSs introduces additional complexities which are likely to be new to the particular site and persons responsible for conducting this activity. It is important therefore that procurement is managed by the most appropriate people. PTOs are experienced bus procurers but may not be the best suited to manage the procurement of a HRS which is fundamentally different from a refueller for diesel.

The FCBs and the HRS must be compatible and be able to combine to ensure quick and reliable refuelling. For example, the type of hydrogen tanks onboard the buses does have an impact on the design of the HRS. 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. The procurement of both items should therefore be done in close collaboration, in order to ensure this happens.

While FCBs are zero emission locally, operating them should also contribute to reduce emissions overall. This is why aiming for ‘green’ hydrogen fuel supply is important. However, a widely agreed definition of ‘green hydrogen’ is not yet available, and some suppliers will want to provide individual solutions. Staying open to these is key to achieving a satisfactory outcome.

Specifying for outcomes can largely overcome many of the issues related to procuring of FCBs and HRSs (for example, specifying the required dispensing capacity of the HRS during an overnight refuelling window rather than its storage tank size). It is also important that issues of performance, warranty, maintenance and supply of parts are clearly understood and agreed by all parties and well documented in the contracts. Only this will count after the contracts are signed.

Stage 4 – Deployment and Operations

At the date of collection of the information in this Chapter (up to August 2021), a majority of JIVE and JIVE 2 sites had entered the Deployment and Operations Stage. However only 4 sites had reached the Regular Operations sub-stage. Consequently, the related chapter currently provides considerably more information on Deployment than on Operations.

The Deployment and Operations Stage has mostly 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 hydrogen supply meets the full operational demand has also sometimes been problematic.

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, with suppliers, and among project stakeholders is critical.

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.

Summarising Case Study

Telling the story of an 'ideal' FCB acquisition project provides a more digestible summarising tool for the wealth of information within this resource. If only this is considered, readers will have had an overview of much of what the experience of others can provide. Hopefully, however, it will also encourage them to delve further.

Issues to be Addressed to Support Future FCB Deployment

The gathering of Best Practice information from the participants in the JIVE and JIVE 2 projects has produced a number of insights and suggestions on resolving issues relevant to supporting an easier uptake of FCBs. These may also be useful in speeding up the pathway to full commercialisation of FCBs. They relate to:

- Further Growing and Better Supplying the Demand
- Ensuring Experience is Shared
- Providing the Right Frameworks.

Tackling these issues could be considered for action by the Clean Hydrogen Partnership and 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.

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List of Abbreviations and Terms

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
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)
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 Introduction

Increasing numbers of local and regional public 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.

0.1 Objectives of the JIVE / JIVE 2 projects

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

The objectives of both projects can be summarised as follows:

- Deployment of 298 zero emission FCBs across Europe (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 (2022/23) 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 are also running in parallel and in close cooperation with the MEHRLIN project, which is funded under the Connecting Europe Facility (CEF) for Transport. Most of the Hydrogen Refuelling Stations (HRSs) for the JIVE sites are implemented and operated within the MEHRLIN project. Its overall objective is to demonstrate a financeable demand-led business model for HRSs.

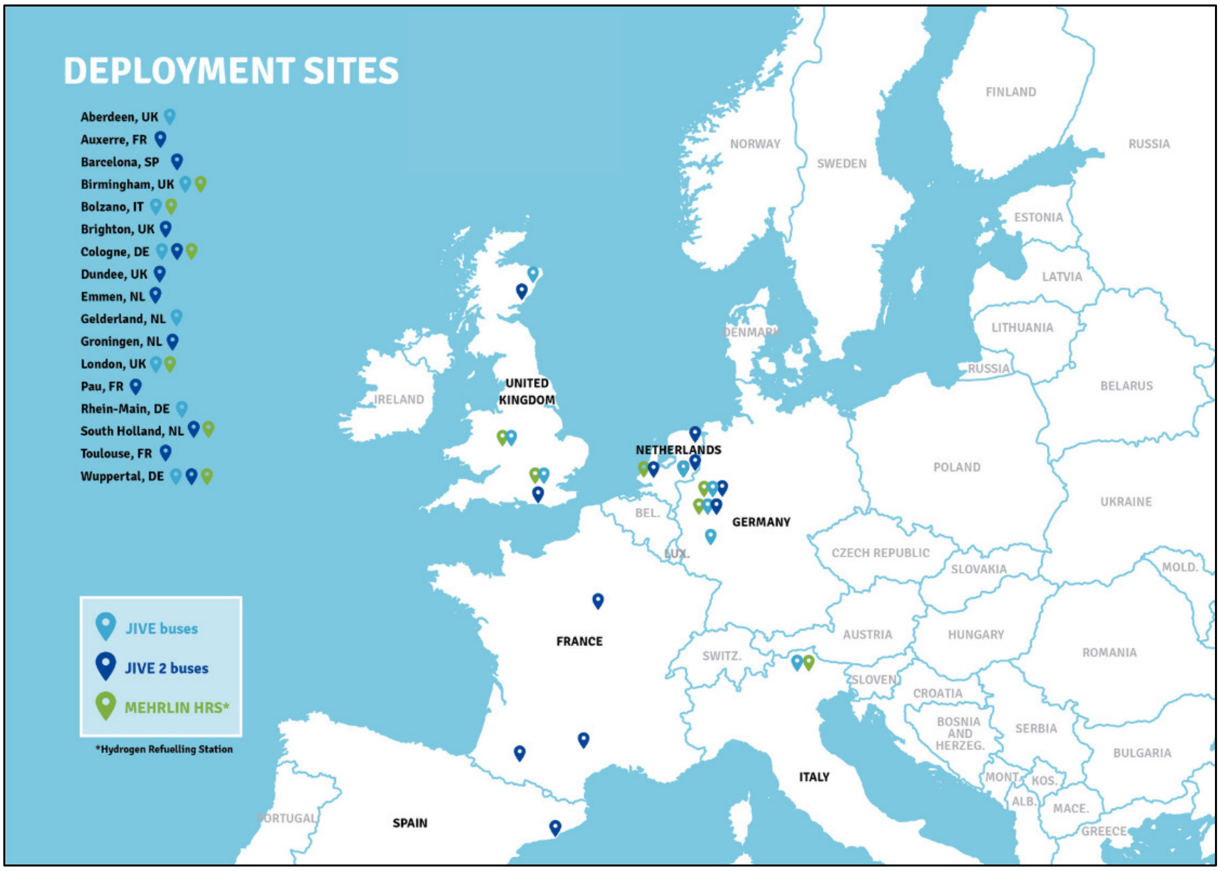

Figure 0-1: Deployment sites in JIVE and JIVE 2.
The local fleets range from 5 to 50 FCBs, typically 10 to 20.

The number and location of sites in the JIVE and JIVE 2 projects has varied over time as some cities have left and new ones have joined, sourced from a reserve list of interested cities. 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.

0.2 Context and objective of this document

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.

The main objective of this document is to bring that information together in 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 (including expectations of deployment sites) can also be important for technology suppliers.

This report documents the learning that has occurred in the JIVE/JIVE 2 projects up to and including the early operations of some of the FCBs and HRSs.

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 at least as important, or arguably more important, than approaches that worked well from the start.

A series of Best Practice and Commercialisation Reports has been scheduled as the projects progress. This contributes to rapidly transferring a range of local experiences on to other stakeholders. This document constitutes the third Best Practice Report under JIVE and the second under JIVE 2. Note that this document is concise and focusses on key issues, rather than trying to cover every possible aspect or issue that may occur in the course of demonstrating FCBs. Key information is provided for each stage up to Stage 4, plus references on further resources that have been of use for the JIVE/JIVE 2 sites or in earlier demonstration activities.

0.3 Information gathering and processing method

The local coordinators of the demonstration cities and regions are regularly requested to provide input, via questionnaires, on their project progress, successes, Challenges encountered and Best Practice solutions found. Five rounds of questionnaires have been used as the basic instrument for gathering information so far. Added to these have been 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.

To assist respondents to focus on particular areas of the projects, the information requested has been broken down into Stages and sub-stages. Project Stages have been described as in Figure 0-2. 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.

This report is structured according to the Stages and sub-stages defined in Figure 0-2 (see Section 0.4 below). In line with the progress achieved at most sites by August 2021, it deals with all Stages up to including early information on Regular Operations.

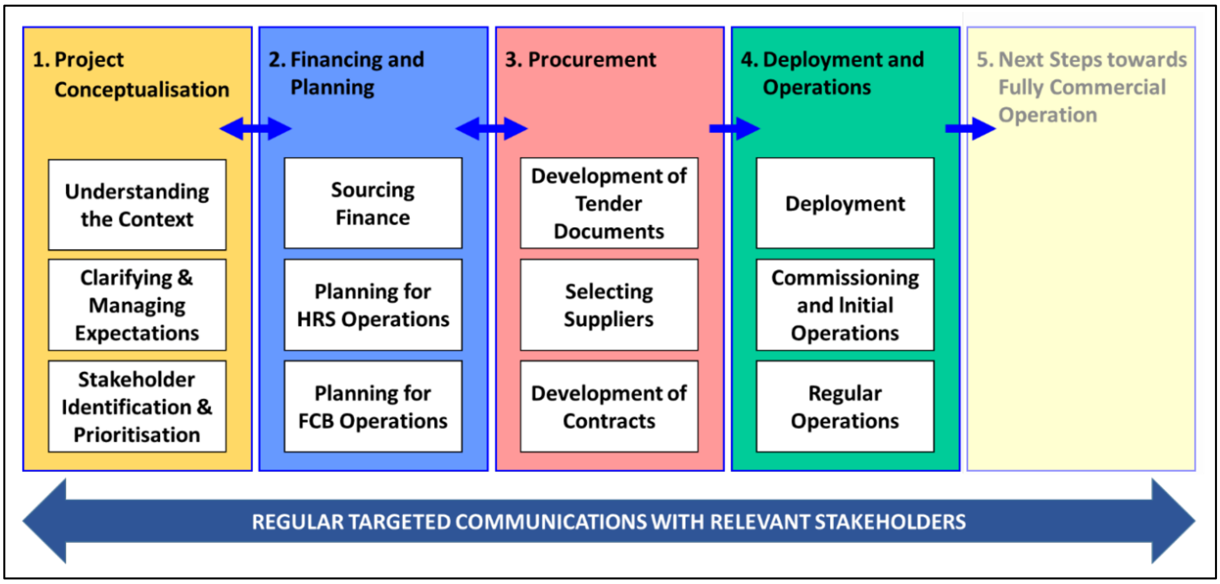

Figure 0-2: Stages and sub-stages[1] of a project to demonstrate FCBs and their hydrogen fuel infra-structure.
In line with the progress achieved at most JIVE/JIVE 2 sites by autumn 2021, this report deals with all stages up to including early information on Regular Operations. Developing a plan for "Regular targeted communications with relevant stakeholders" is covered in Stage 1, in the context of "Stakeholder Identification & Prioritisation".

Round 1 questionnaires were 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 19 sites[2]. At that time, 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.

[1] The former sub-stage 'Construction' in the Best Practice Report 2020 has been renamed 'Deployment' for the reason that, while construction is a major part of this sub-stage, the word is more inclusive of some other activities that occur at this point, including training.

[2] Cologne and Wuppertal being involved in both projects were counted separately for JIVE and JIVE2 in this round because their state of progress was not the same in the two projects, e.g. regarding FCB procurement.

In Round2 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.

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.

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 still working on the early stages up to and including Procurement plus additional questions on Expectations etc. [3/4 responses (2 responses from one site)]

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 feedback from the sites is 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.

0.4 Structure of report

Apart from the introduction, this report has 5 chapters:

- **Chapter 1** discusses **Stage 1 – Project Conceptualisation**. This Stage has been addressed in three sub-stages
  - Understanding the Context
  - Clarifying and Managing Expectations
  - Stakeholder Identification and Prioritisation
- **Chapter 2** discusses **Stage 2 – Financing and Planning**. This stage also has been addressed in three sub-stages
  - Sourcing Finance
  - Planning for HRS Operations
  - Planning for FCB Operations
- **Chapter 3** discusses **Stage 3 – Procurement** of HRSs and the FCBs. Each is discussed in relation to:
  - Development of Tender Documents
  - Selecting Suppliers
  - Development of Contracts
- **Chapter 4** discusses **Stage 4 – Deployment and Operations** and is also divided into three sub-stages
  - Deployment: This covers many of the preparatory activities for bus and refuelling infrastructure operations
  - Commissioning and Initial Operations.

- Regular Operations

- **Chapter 5** presents a **Case Study** which provides a narrative summary of key points presented in tabular form in the preceding chapters.
- **Chapter 6** 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.

Additions to the previous Best Practice Report of January 2020 include a new Chapter 0 and an expansion of the (now) Chapters 5 and 6. There are also minor updates in other Chapters.

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.

Next Steps towards Fully Commercial Operation (Stage 5) are considered in Chapter 6 in compiling issues to be dealt with to support the further deployment of FCBs.

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.

It can also facilitate 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 chapters.

Overall, there are two aspects of developing a FCB project which 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, as well as the broader community.

One of the site coordinators stressed the importance of periodically re-reading written resources. 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 in the course of their own project but were not obvious when studying the documents at an earlier stage. In effect, they started to get 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. 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
National and local emission and clean energy requirements are playing an important role
The future ambition / next step, expressed via channels outside the questionnaire round, is 50+ buses per site and whole depots moved over to FCBs
Note: As of 2022, there are already sites where 50+ buses are being deployed and others where there is the intention to have whole depots moved over to FCBs</td></tr>
<tr><td>City wants cleaner air</td><td>13</td></tr>
<tr><td>City 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:
Ambition to be in the forefront in innovation generally, and public transport in particular
PTO/PTA wants to showcase emission-free transport
Regional policy on zero emission public transport: From 2025 only emission-free buses to be ordered
Part of regional hydrogen strategy / Part of an industry strategy
To use hydrogen for storage of wind energy
Part of overall transition to renewable energy in the region</td></tr>
</table>

Table 1-2: Project Conceptualisation – Challenges and Best Practice Solutions.
Based on 22 Responses.

Challenges	Best Practice Solutions
Starting with an innovative project • Hydrogen is a new fuel in public transport, and its introduction poses challenges very similar to other innovative projects • 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** • 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 fulfil local needs better. • Know and connect with the political agenda for low carbon vehicles at any or all of local, regional or national levels **People make hydrogen happen** You will need: • A committed Project Team consisting of knowledgeable and experienced staff • Effective, collaborative team work to develop the project and overcome challenges • Committed and well informed organisational decision makers and elected officials
Political/Legal environment can intervene • 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** • Avoid or mitigate against getting caught up in election cycles • Understand legal frameworks for tendering, contracting, safety permitting
Preparatory work can be extensive • Innovative projects mean a lot of information needs to be gathered and there are not a lot of templates available to follow • A key challenge is to understand and accept that there will be things you don't know 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** • Find out as much as you can about FCBs and HRSs early in your project conceptualisation; re-visit resources regularly as questions arise • Be clear on the benefits of FCBs – but be equally honest about the costs and risks • Visit city sites where FCBs are in operation to obtain first-hand information • Attend workshops offered by ongoing projects to learn about experiences, challenges and solutions • 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: ➢ The "Clean Vehicles Directive" on the promotion of clean and energy-efficient road transport vehicles has recently been revised. It is going to impact on the procurement strategies of PTAs/PTOs: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0033 • The FCH JU (now the Clean Hydrogen Partnership) has co-funded the major FCB demonstration projects under the 7th Framework Programme and Horizon 2020. It can be expected that its work is going to continue under Horizon Europe (2020 - 2027), particularly in terms of promoting "hydrogen regions": https://www.clean-hydrogen.europa.eu/index_en • Basic properties of hydrogen including comparisons with other energy carriers/fuels: http://www.h2data.de/ Dedicated resources for Funding, Planning and Procurement can be found in corresponding tables in the following chapters.	• Visiting and talking to experienced cities in your country/elsewhere in the EU • Knowledge Briefs in 9 European languages: https://www.uitp.org/publications/fuel-cell-buses-best-practices-and-commercialisation-approaches/ • An "Operators Guide' to Fuel Cell Bus Deployment" can be found on https://fuelcellbuses.eu/projects/jive-2 • More reports from JIVE and JIVE 2 will become available over the coming months at https://fuelcellbuses.eu/projects/jive and https://fuelcellbuses.eu/projects/jive-2. They will include details on the different local projects, such as FEBUS in Pau (France) as part of JIVE 2: https://fuelcellbuses.eu/public-transport-hydrogen/brochure-fuel-cell-bus-pau-busworld-2019 • Reports from CHIC project for FCB demonstration (2010 – 2016): https://fuelcellbuses.eu/projects/chic including: ➢ Recommendations for Hydrogen Infrastructure in Subsequent Projects • Reports from the NewBusFuel project on large scale HRSs, including a Guidance Document: http://newbusfuel.eu/publications/	• Further reports from CHIC project at https://fuelcellbuses.eu/projects/chic including: ➢ Influencing factors to the acceptance of fuel cell and hydrogen technologies in public transport (focussing on bus drivers, stakeholders and the general public) ➢ Extract from the above report with key learnings ➢ Issues of concern to external stakeholders and critics and pathways to their resolution; also includes an update of this report regarding changing views after two years • "People, Transport and Hydrogen Fuel: Guidelines for Local Community Engagement when Implementing Hydrogen Powered Transport", from the HyFLEET:CUTE project (2006 – 2009) https://fuelcellbuses.eu/publications • "Sustainability Assessment of FCBs in Public Transport", March 2018 http://www.mdpi.com/2071-1050/10/5/1480/pdf

1.2 Sub-Stage: Clarifying and Managing Expectations

Local JIVE and JIVE 2 coordinators were asked about their 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 on quantitative targets e.g. expected availability of the FCBs and HRSs, fuel consumption, time required to refuel a bus. In summary, site coordinators have high project expectations. They sometimes exceed the targets defined in the project proposals. Details can be found in Annex A. These initial expectations will be compared with what is experienced at mid-term and towards the end of the projects.

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, money 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 course of 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 – Expected major outcomes of the local projects.
Six options provided, one or more options could be selected. Based on 22 responses.

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 current bus prices and operating costs were a concern (see Chapter 2), most respondents anticipated that an acceptable (low) level of cost will be achieved in the future • While fossil fuel technology is not considered to have a future, less than half the respondents seem 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, this 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 stakeholders as such, it includes other parties of key relevance, for example cities/sites with existing experiences in 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.

Good FCB specific templates for stakeholder interaction and developing a Communication Plan are available. For example, the document "People, Transport and Hydrogen Fuel" (see Table 1-3) provides some detail on this.

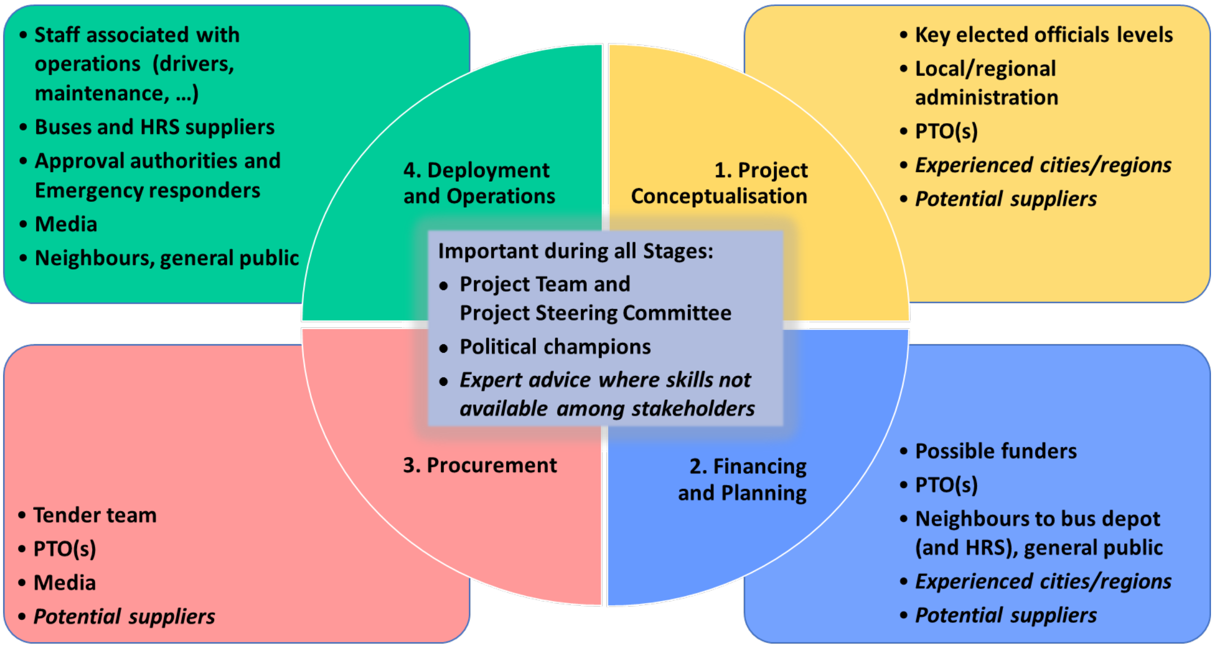

Figure 1-1: Sample Map of important Stakeholders and (in italics) further parties of key relevance during the Stages of a FCB deployment project.

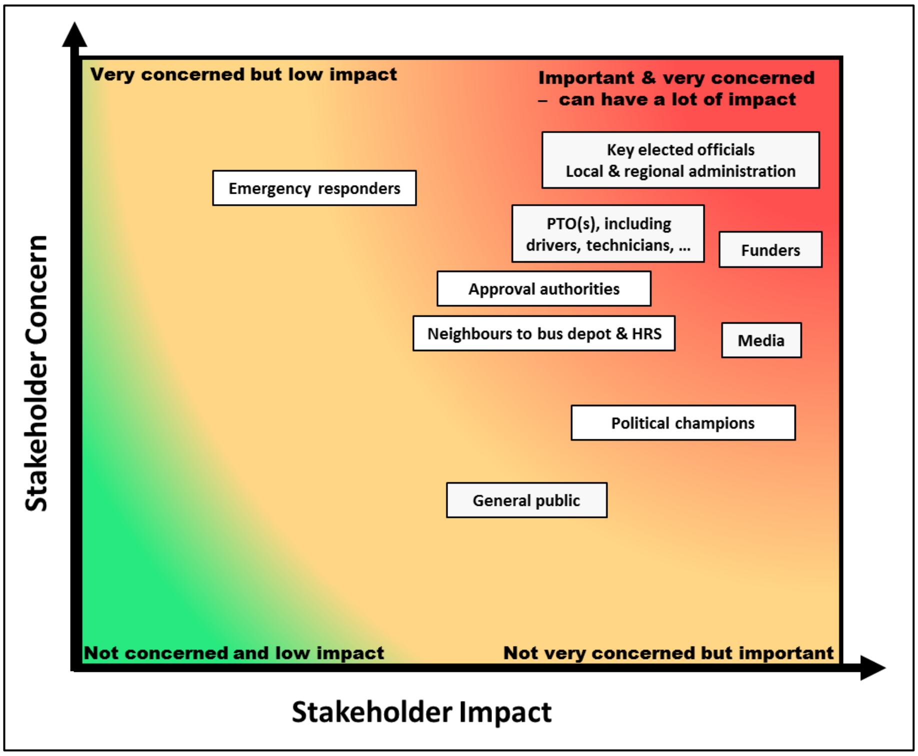

Figure 1-2: Example of a Community Stakeholder Prioritisation Map.

It is important to be aware that the criticality of the individual stakeholder groups varies from site to site, so 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" (see Table 1-3 above). HyFLEET:CUTE, 2009.

While this attention to stakeholder engagement appears self-evident, 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 innovatory 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. Given the current state of development of FCBs and HRSs, it is highly likely that as of the time of writing, the additional costs over and above the costs of buying and operating conventional diesel or natural gas buses can only be met by grant funds of some sort and. One of the goals of FCB demonstration at scale is 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 frequently 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.

The major source of this additional money in JIVE and JIVE 2 has been the Clean Hydrogen Partnership. Funds from the CEF through the MEHRLIN Project have also supported the HRS implementation at many JIVE projects 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.

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 not an easy task 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[3].

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.

[3] The Clean Hydrogen Partnership will not fund pure FCB demonstration projects in the future. However, buses and their infrastructure can be co-funded 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.

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 takes into account, 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.

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

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

Level and complexity of costing:

- Uncertainties around pricing of FCBs, HRSs, and H_2 fuel
- Demand for FCBs is currently higher than supply, so the industry competition is immature
- Inexperience with costing CAPEX and calculating revenue in short term (demonstration) projects
- Inexperience and complexities of costing OPEX
- Costing uncertainty is compounded by multiple options for H2 fuel supply

Lack of Information:

- Not enough general experience to be confident about bus performance in operations
- Lack of financial models

</td><td>

- 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
- Learn from other cities with experience; some will be willing to provide sample specification information and provide figures from their operations

CAPEX:

- Consider procuring jointly with other sites to get better prices for the FCBs through higher volume (see Chapter 3). This can work, provided the sites have similar requirements and specifications, and similar regulatory structures
- 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

OPEX:

- H_2 pricing can be difficult. A lower price can be achieved if a minimum purchase quantity is guaranteed to the supplier and the contract is lengthy and offers break clauses (ability to stop the contract at defined points in the future)
- Seek to define Green H_2 and be aware that sources can be limited (for information on H_2 supply and Green H_2 definitions see Table 2-5 and Chapter 3 on Procurement)
- Current (2021) indicative bus performance in terms of efficiency and maintenance costs will be available through the JIVE projects.

TCO:

- 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.
- Be sure to include the requirements of maintenance, training and certification for a new technology
- Be sure to include the residual value of the buses and the HRS

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

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

Challenges	Best Practice Solutions
Knowledge of Funding Sources and Interaction with Funders: • Knowing and connecting possible funding sources • Convincing funders • Timeliness • Making sure that interactions between different sources of funding do not interfere with each other • Weaving purchase of new buses into routine fleet investment **Politics:** • Changes in/uncertainty regarding the political situation/agenda • 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 • 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 • Connect with funders informally or find good intermediaries or experts • Present a thorough business case to show that you are serious about your project (see Table 2-3) • Service funders well; never assume reliable, lasting commitment • 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 • Consider employing experts to seek & prepare funding proposals • Be aware there may be issues that arise: ➢ from providing subsidies to private organisations (e.g. PTOs) ➢ about the ownership of assets purchased with funder input and ➢ in trying to coordinate with the investment cycle of PTOs • 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) • 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	• Report "Business cases to support fuel cell bus commercialisation" (2017): http://newbusfuel.eu/publications/ 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 *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** • 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 • Innovation Fund for demonstration of innovative low-carbon technologies.: https://ec.europa.eu/clima/policies/innovation-fund_en • Just Transition Fund: https://ec.europa.eu/regional_policy/de/funding/jtf/ • 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 • 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/ • 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 **National** • 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 **Private Investment** • Hy24 Clean Hydrogen Investment Platform: https://www.hy24partners.com/ • 5t Hydrogen Financing the Foundation of Hydrogen Economy: https://fivet.com/fivet-hydrogen

Suppliers: While immature, Industry may work flexibly with purchasers to help them achieve their goal	• https://www.fuelcellbuses.eu/suppliers lists the known manufacturers of FCBs, HRSs & some component suppliers • https://www.hydrogeneurope.eu/directory/industry provides a directory of their industry members
Appeal to social, environmental & cost benefits of clean air/reduced emissions	**Calculating external costs avoided** • 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 • "Sustainability Assessment of FCBs in Public Transport": http://www.mdpi.com/2071-1050/10/5/1480/pdf • Total Cost and Revenues of Ownership (TCRO): 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 numerous of these have been re-iterated in the Deployment and Operations Stage (Chapter 4). This is because, some of these challenges related to planning only come into real focus when operations are imminent. JIVE sites reported a lot of activity during Deployment to cover things 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 A summarises quantitative expectations for FCB and HRS performance as expressed by the sites at the beginning of the JIVE and JIVE 2 projects (as explained in Section 1.2).

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

	Best Practice Solutions
1	<u>Visit/talk to experienced sites</u>: This strategy is perhaps the most helpful for all stages of developing and implementing your project. It can help you at the outset to understand 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: Buses need a refueller during their commissioning phase
3	Plan for slow progress: Roadblocks 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 on your 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
4	Plan for clear and consistent communication: 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.: • A PTO may not be the best to procure a HRS but they know a lot about buses • PTO or PTA may be better able to procure HRS location site than the HRS supplier • A single “turnkey” HRS supplier has been found to be a better option by some
6	Resource the planning stage well (people and time) : Thorough planning = smooth(er) procurement; expert assistance will be of help
7	Plan to set up a broadly-based tender team: Tender teams need to have a wide range of expertise: apart from at least one member experienced with conventional tendering, this includes understanding of technical (FCBs/HRSs), financial, risk management, contracting and legal frameworks issues(more on this in Ch. 3)
8	Engage early, often and widely: political advocates, city administration; local authorities (including firefighters etc.); in particular: • 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 • Talk to FCB and HRS suppliers: Get as much understanding of the technology as possible (see also Table 2-5)
9	Permitting: Permitting remains a big job 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 do not know how to handle it; Best Practice has been to “Educate your Regulator” i.e. have "unofficial" discussions with the authorities before handing in your applications for permits, introducing them to the field and to what has been successfully deployed at other sites, presenting your plans/solutions, never asking them “What should I do?”; be willing to compromise on technical details
10	Data from FCBs and HRS: The JIVE Projects have shown that performance data you need for seamless integration of both the FCBs and the HRS into your 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 • 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 on • 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 • 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 & conditions is complex; technical planning can be affected by changing national regulations	• Specify for Local Needs: As part of the dialogue among local stakeholders, review and refresh local needs such as HRS ideal location(s); 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 back up supply** (numerous sites have mentioned that at the Operations stage this has been essential to smooth operations; see section 4.2) • 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 • 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 • H_2 Supply: All H_2 supplied must be ‘green’ to fully address climate issues in particular; definitions of Green H_2 are still developing and in the short term green supply may not be possible (see Table 3-3); consider all supply pathways offered and source well to wheel investigations of emissions - 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; think about the need for redundancy of components in the HRS (e.g. compressors, dispensers, piping etc.) • 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 • 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 • 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 & safety; training requirements; technical performance of H_2 technology • Modifying Existing Depots / Routes: FCBs may need more space in depots; determining routes - not all routes are suitable; different or additional maintenance equipment and skills will be needed • Lack of Information: Bus fuel consumption figures and drive characteristics and power specification details are not as readily available as for their diesel counterparts • 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 • 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 for engaging with commercial PTOs • 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 • Become familiar with Local Needs: Review and refresh local needs – routes, depot location, saleability; supply chain requirements; warranties and repair arrangements; understand the issues • Awareness Raising and Training: Plan for this considering bus drivers & maintenance technicians, first responders, bus users etc. (see Table 4-4) • 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 • Maintenance: Consider carrying out all or part of the maintenance in-house - this will help you understand the technology more rapidly (see also Table 4-2 on bus maintenance procedures) • Insurance: Engage early with insurers as few have experience of FCBs • 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 or search the membership list of: https://www.hydrogeneurope.eu/directory/industry If possible, visit their factory and use your performance criteria to question them on performance. For a map of sites with existing and planned HRSs for FCBs in Europe see: https://www.fuelcellbuses.eu/
Talking to and/or visiting demonstration sites with operating FCBs and HRSs	For JIVE sites see Figure 0-1 or: https://www.fuelcellbuses.eu/projects/jive and https://www.fuelcellbuses.eu/projects/jive2 Currently (December 2021) the most experienced active sites are Aberdeen, Bolzano, Cologne London and Wuppertal. 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, including CHIC and NewBusFuel	On https://fuelcellbuses.eu/publications for example: • Public summary of the Final Report of the CHIC project (2010 – 2016) • Guidance for HRS consenting phase (JIVE 2) • Introduction to fuel cell buses: Guidelines for operators (in German)
Particular reports on planning for HRSs	On https://fuelcellbuses.eu/publications for example: • Info pack about the hydrogen infrastructure in Pau/France (JIVE 2) • Recommendations for hydrogen infrastructure in subsequent projects (CHIC) On http://newbusfuel.eu/publications/ for example: • Guidance document on large scale hydrogen bus refuelling • Review of regulations codes and standards with respect to hydrogen bus scale fuelling
Particular reports on planning for FCBs	On https://fuelcellbuses.eu/publications for example: • Operator’s Guide to Fuel Cell Bus Deployment (JIVE 2)
Well-to-wheel emissions	A recent study (October 2021) can be found here: https://www.zemo.org.uk/assets/reports/Zemo_Hydrogen_Vehicle_Well-to-Wheel_GHG_and_Energy_Study_2021.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 particular site and persons responsible for conducting this activity. For example, standards for refuelling heavy duty vehicles (fills of >10kg H_2) are still under development, 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 refueller must be compatible and be able to communicate, to ensure quick and reliable refuelling. For example, the type of H_2 tanks onboard the buses does have an impact on the design 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 re-fuelled very fast. Today, Type IV tanks are the choice of the most bus suppliers because they are lighter and also cheaper. They were first used in FC cars. Type IV tanks are fibre-wrapped plastic vessels. Their lower thermal conductivity slows down the dissi-pation 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 80°C can be ensured via a conservative (= slow) refuelling process or by H_2 pre-cooling. The need for pre-cooling also depends on the ambient temperature. Standardisation in this respect in still ongoing (February 2022).

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 pro-cess conducted by a single organisation such as the PTO. One city site even put out a single 'outcomes-based' tender for the complete system of buses and refuelling station. This was successful, and other sites consider this as an option for the future.

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 where and when required.

This solution is 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 overnight 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 recommended as 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) are clearly understood and agreed by all parties and well documented in the contracts. **Only this 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 Chapter is structured by initially documenting Challenges and Best Practice Solutions that are common to 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 with regard to 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.
The market for both HRSs and FCBs is immature and delivery times can be unrealistic; availability varies greatly across different EU countries	• Do a market review: Determine which manufacturers are willing and able to deliver • Very important to use manufacturers and experienced sites as knowledge resources • 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 4-2 and Table 4-10) • 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.) • 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 • Iterative process to contracts, particularly if many parties involved • 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
Reliability and scalability cannot be assumed	Negotiate for scalability and specifically address reliability requirements – the most important factor for a public transport system (e.g. the length of the overnight windows during which the HRS will always be available)
• Maintaining communications with and between stakeholders throughout procurement process	• 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); funders should feel informed at all times

• Significant training time is required for bus drivers/mainte-nance technicians/bus depot people	• Training by suppliers: Factor this into all procurement documentation
Safety assessments require attention (see also Table 4-8 on Safety in Operations)	To address potential reservations by local authorities lacking experiences, be pro-active; consider resourcing an assessment for the HRS and the Bus Maintenance Facility; profes-sional 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 HRS 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 the situation with HRS technology or suppliers yet. 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.

Most recently there has been a rise in “all in" offers. To ensure accountability, the PTO or PTA deals with one point of contact who offers vehicle, hydrogen supply, HRS, and maintenance in a complete package. While none of the JIVE/JIVE 2 sites have used this approach, this is under development from the industry at the moment which are helping to make FCBs more accessible.

The reasons why there is a lack of standard HRS configurations for FCBs include: a small number of such HRSs so far (while most sites have special requirements related e.g. to limited footprint available), the type of H_2 supply (on-site generation, trucked in) and uncertainties around the need for pre-cooling (as explained above).

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 • Determining capacity and redundancy needed • Meeting innovative technology requirements; developing the evaluation criteria to match the requirements • Permitting requirements • Synchronising bus and HRS delivery • Implementation of HRS in bus depot with limited space and coordinating with other new technologies (e.g. BEBs); allowing for flexible solutions • 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 technical specification output-based; 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 • Set targets for technical outputs e.g. fuel fill times, but do not score or pay more for times that beat them; ensure contract includes data provision to monitor performance • Be clear on outcomes required and their consequences (revenue implications; warranties; maintenance) and have them confirmed by the potential suppliers • Require at least one visit of potential suppliers to location for HRS; the site specifics will affect proposal details and agreement to work with FCB supplier • Choose correct tendering procedure: large gas companies and smaller companies can provide the HRS, the latter may be more interested in submitting a proposal • Set target fuel price (combined fuel and maintenance) and set a price cap. • Consider whether to separate into two: 1. HRS hardware; 2. Fuel supply contract (see also following table)
2. Selecting Supplier	
• Manufacturers unresponsive; poorly written proposals • Matching proposal specifications with tender specifications / technology offered not meeting expectations • Deciding which supplier is best choice due to quite different concepts presented	• Invite quotes for standard and variant bids (delivered or on-site) to see what can be offered • Include 'innovatory solutions' as one of the evaluation criteria – technical and commercial (e.g. scalability) • 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 • 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
'Green' H_2: • A widely agreed definition of 'Green' H_2 is still not available • 'Green washing' by providers is also still an issue. • Funding bodies generally want Green H_2;	The CertifHy projects have developed a system for guarantees of origin for Green H_2 (originating from renewable sources as defined in article 2 of RED II) having a GHG balance below a defined threshold. (See https://www.certifhy.eu/go-labels/). There is also "CERTIFHY™ LOW-CARBON HYDROGEN", originating "from non-renewable origin, nuclear or fossil energy using carbon capture and storage (CCS) and potentially carbon capture and utilization (CCU) which is yet to be defined by European Law and having a greenhouse gas balance below a defined threshold. (quote from https://www.certifhy.eu/go-labels/).
H_2 Price: 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 • Co-locate with an industrial large-scale hydrogen consumer for better prices • It is possible to get a long term contract at a better price if significant volume is assured. These contracts can contain break clauses (see Table 2-1). • Set a target price and a price cap • Evaluate on TCO basis, including 'beyond project' costs
H_2 Purity: 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 as yet been implemented
H_2 Metering: Measuring accurately enough the amount of H_2 refuelled (and supplied from external sources, if applicable) is still not a fully resolved issue	Ensure this issue is discussed with suppliers and understood by the local stakeholders; enhanced protocols for fast and reliable gauging have been developed but still need to be verified and approved by weights and measures authorities

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. This approach is perhaps most pertinent to FCB procurement. 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 are 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 the Benelux countries, France and Southern Europe, the German speaking countries including Northern Italy, Northern and Eastern Europe, and 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 is live for five years from 2018 and can also be used by sites from other countries to order their FCBs. However, comments from the participant sites, particularly London – the lead site – suggest that the process was very involved and led to considerable additional administration costs to the sites, 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 from each other, received an offer and proceeded on the basis of the original tender. They finally placed an order for 40 vehicles. The other two sites tendered individually. Cologne regional transport has subsequently followed this with another order for 100 buses (May 2022), the largest single order for FCBs in Europe to date.

Recommendations with regards to 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 June 2022. 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: Lack of mutually recognised guidelines for technical specifications for FCBs (standardisation); e.g. concerning fuel consumption • Joint Procurement: Specifying the buses so that they meet the requirements of all the partners/sites involved • Project Compliance Requirements (where part of a third party funded project) • Sticking to Tender Laws while procuring a new technology in an immature market environment	• 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 • Preferably work in with a PTO's investment cycle and be prepared to support them with information and advice on where to source information about the new technology • 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 • Negotiation and communication with suppliers is 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 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): • Partners need willingness to compromise on common bus specifications. • Appoint a single coordinator for discussions and later on negotiations with suppliers. • 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 • 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 (buses/tenders of under ten vehicles seem to struggle attracting interest); purchaser at a disadvantage; delivery time negotiations can be difficult • 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 • 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. • Maintenance costs can increase significantly after around the third year of operation, due to increasing replacement/refurbishment costs of some components. • Evaluating responses requires expertise in H_2/fuel cell technology	• Communication and flexibility to negotiate with suppliers are critical throughout the tender process • Negotiate add-ons once manufacturers have placed bids • Some manufacturers more able/willing, to lower prices in response to scale. • 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 • Lack experience in procuring FCBs: Technical and legal details • 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 / agreeing roles and responsibilities in terms of risk • Fuel Cells: Reassurance needed that FC stacks will last	• Absolute clarity between all parties on outcomes wanted and compliance with tender / contract details especially where there are sub-contractors involved • 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 • Include a requirement to work with HRS supplier • 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 & HRS suppliers about their product specifications and experiences	For lists of suppliers see: https://fuelcellbuses.eu/suppliers or search the membership list of: https://www.hydrogeneurope.eu/directory/industry If possible, visit their factory and use your performance criteria to question them on performance.
Talking to and/or visiting demonstration sites with operating FCBs and HRSs	For JIVE sites see Figure 0-1 and/or: https://www.fuelcellbuses.eu/projects/jive, https://www.fuelcellbuses.eu/projects/jive2 and/or https://fuelcellbuses.eu/ Currently (Dec. 2021) the most experienced active sites are Aberdeen, Bolzano, Cologne, Groningen, London and Wuppertal. 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, including CHIC and NewBusFuel	On https://fuelcellbuses.eu/publications for example: • Operators' guide to fuel cell bus deployment (JIVE 2) Documents with collation of training materials for staff involved in bus operation, for HRS users and for first responders will become available in 2022.
Particular reports on planning for HRSs	On https://fuelcellbuses.eu/publications for example: • Recommendations for hydrogen infrastructure in subsequent projects (CHIC) On http://newbusfuel.eu/publications/ for example: • Guidance document on large scale hydrogen bus refuelling • Strategies to ensure adequate redundancy • Agreed definition of availability for bus depot fuelling stations and recommendations
Particular reports on planning for FCBs	On https://fuelcellbuses.eu/publications for example: • Lessons learnt from joint procurement of fuel cell buses (JIVE) • Final report on the strategies for joint procurement of fuel cell buses (Report for the FCH JU, now the Clean Hydrogen Partnership) On http://newbusfuel.eu/publications/: • Common bus operator requirements for future tendering processes (focus: links/interdependencies FCBs/HRSs)

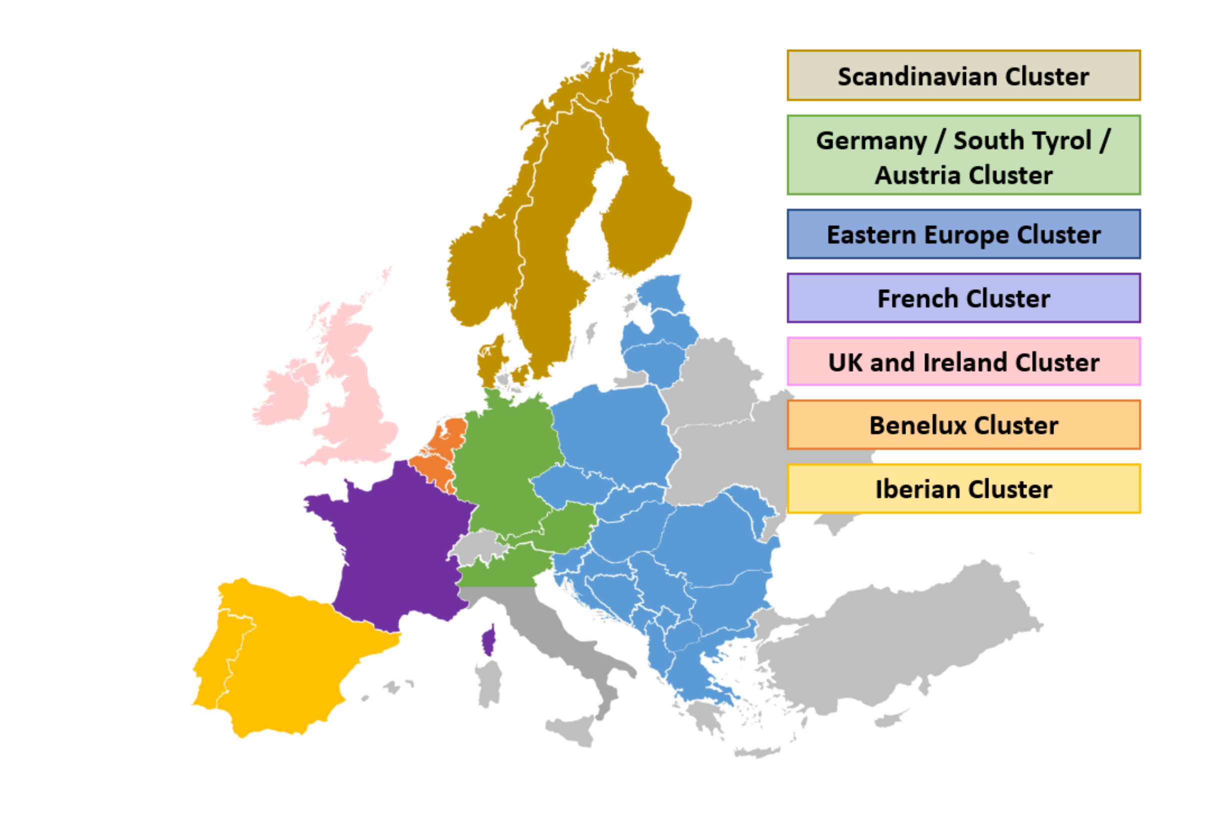

Figure 3-1: Map of the seven regional clusters to advance FCB deployment.

Table 3-6: Contact details for regional and national fuel cell bus groupings.
As of June 2022.

Cluster / Country	Contact
Germany / South Tyrol / Austria	Energy Engineers: Frank Koch, koch@energy-engineers.de
French	Element Energy: Elise Ravoire, elise.ravoire@element-energy.co.uk
UK and Ireland	Element Energy: Michael Dolman, mike.dolman@element-energy.co.uk
Benelux	Rebel Group – within JIVE, mainly for Netherlands: Marc van der Steen, Marc.vanderSteen@Rebelgroup.com WaterstofNet – outside of JIVE, whole Benelux: Stefan Neis, stefan.neis@waterstofnet.eu
Poland	Reform Institute: Aleksander Sniegocki / Kuba Zawieska aleksander.sniegocki@ireform.eu, kuba.zawieska@gmail.com
Spain	Element Energy: Eva Baker, eva.baker@element-energy.eu
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 Chapter (up to September 2021), a majority of JIVE and JIVE 2 sites had concluded the Procurement Stage and have 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 summer 2021 only 4 sites had reached the Regular Operations sub-stage. Consequently, this chapter provides considerably more information on Deployment than on Operations.

The Deployment and Operations Stage has mostly 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.

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, with 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.

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)
- Determining Bus Maintenance Procedures (Table 4-2)
- Route Planning (Table 4-3)
- Awareness Raising and Training (Table 4-4)

Table 4-5 lists useful resources.

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 touched upon in Chapter 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.

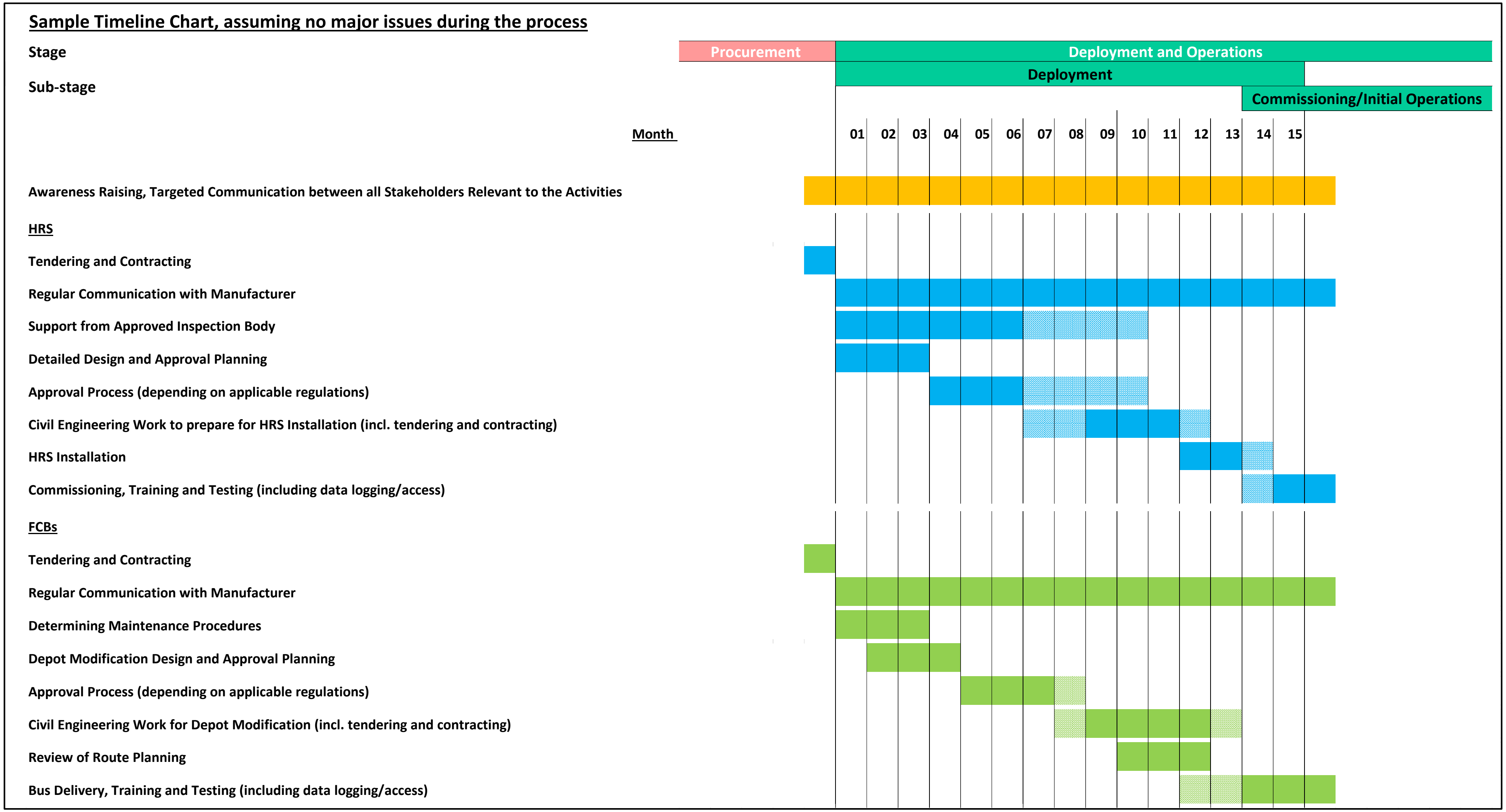

Figure 4-1: Indicative Timescale for the Deployment sub-stage.
Cross-striped period indicate possible extra time needed or potential for an earlier start. Based on a chart developed by Regionalverkehr Köln and expanded with their support.

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

Challenges	Best Practice Solutions
Parking: • Determining how to configure FCB parking along with diesel parking and possible BEBs	• 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. • A "safe" parking area may be required for buses that are awaiting checks for (suspected) H_2 leaks etc.
Bus Maintenance Facility: • 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 • Lack of standards or "How to" Guide for hydrogen-ready retrofits and new facilities. • Permitting in this area is still developing and authorities still uncertain in this area causing delays	• 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. • 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. Figure 4-3 gives an overview of some key cost items. • There are safety specialists who have experience of FCB workshops and can assist with a safety audit that complies with local certification requirements • As has been the case for bus depots previously: **Well designed depots and well-trained staff = safe operations.**
Refuelling: • 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), a few sites located their HRS outside and at distance from the depot. Only during deployment and early operations has it become clear that the effort required for refuelling the FCBs remotely (time, staff) if the buses do not operate on lines passing by the HRS. 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 • There are good resources to help a site decide what is the best option for their context (see Table 4-5 below)

Figure 4-2: Sample layout of a functioning depot in Groningen, The Netherlands.
Left hand photo shows depot parking facilities for BEBs with overhead pantograph recharging at each parking bay. Right hand photo shows one of the two hydrogen dispensers with the washing hall in the background. Photo by permission OV-bureau, Groningen, Netherlands.

Part	Investment cost [€]
1. H_2 specific incremental investment cost for workshop equipment per bay: 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 Extra windows or fire protective doors	5,000 to 15,000
3. Rooftop working: 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 4-3: Cost ranges (2015) 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 4-5.

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 refuelled simultaneously at their parking bays. Photo by permission of SMTU Pau, France.

Table 4-2: Deployment: Bus 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.	• 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 4-4 for more information on Awareness Raising and Training. One site has fully outsourced their maintenance as they do for diesel buses. • During the early commercial deployment of FCBs, geographically close operators should consider pooling their maintenance technician resources • 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 • Manufacturers are starting to use pre-emptive maintenance to monitor when parts are likely to need replacing • Keep existing other procedures adapted for the requirements of a FCB e.g. car wash, indoor fuelling, etc. – these will help reduce costs
• In spite of 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) • 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 4-3: 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 any more 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 • In the case of a private road, tunnel or ferry, the owner may apply different requirements.
• FCBs 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)	• 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. Few problems have been encountered which is encouraging. Nonetheless, it is recommended that all routes are examined and tested.

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

Challenges	Best Practice Solutions
• Groups that require general awareness raising about FCB: ➢ All PTO staff ➢ General public • Groups that require FCB (including safety) training: ➢ Maintenance technicians ➢ Drivers ➢ Refuelling/Cleaning staff ➢ First responders (Emergency Services) ➢ All depot staff – safety basics • The topics to be addressed/focussed on vary from group to group. • Refresher training needs to be scheduled for those most involved to pick up on new employees	Clearly there are technical differences with FCBs (e.g., High voltage components; handling of devices containing H_2). Generally speaking, awareness raising and training have not presented any problems to the JIVE sites • Map the training requirements, possibly per group. Figure 4-5 gives an example of how this can be done • 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 • Training is conducted through classroom learning, workshops and practical experience • Sites have adopted a range of approaches for providing the training including: ➢ Training provided directly by the Bus/HRS suppliers ➢ Train the trainer by Bus and/or HRS suppliers with onsite specialist remaining for a time ➢ Training provided by the PTO with assistance from the Bus/HRS suppliers (train the trainer and/or materials) ➢ Training provided by the PTO with assistance from the Bus/HRS suppliers and involving local/regional training institutions as a means to integrate the information into the formal training system

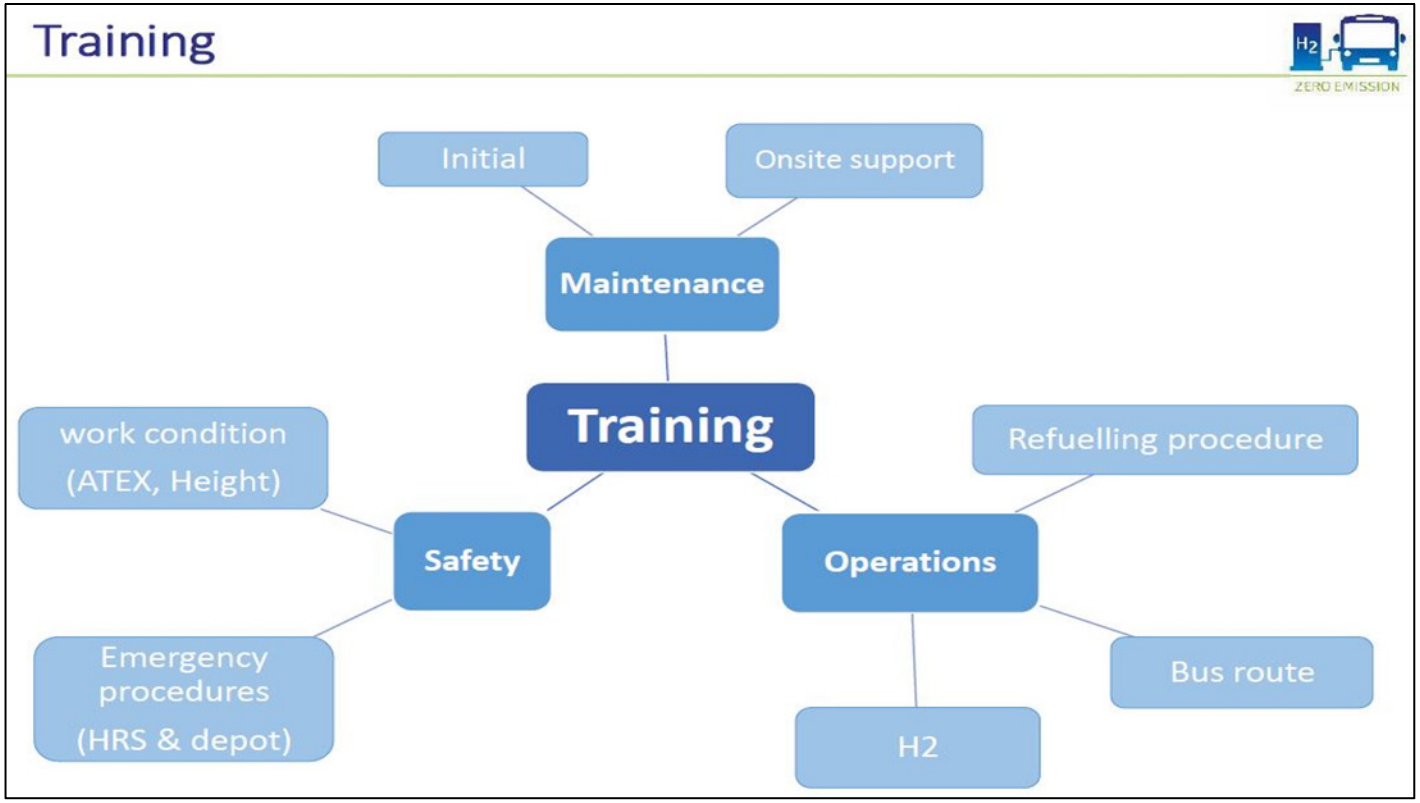

Figure 4-5: Sample 'Map' of Training Requirements.
Source: Syndicat mixte des transports urbains Pau-Porte des Pyrénées.

Table 4-5: Deployment – Useful Resources.

Area of Interest	Resources and where to find them
Depot Upgrade Information • Depot arrangement • Maintenance Facility • HRS Layout	• https://blog.ballard.com/adapting-bus-depots-for-hydrogen (The author of this article was involved with earlier FCB Demonstration Projects) • Indicative Costs of Maintenance Workshop (CHIC project, 2015) https://www.fuelcellbuses.eu/public-transport-hydrogen/analysis-investments-workshops-fuel-cell-buses-and-hydrogen-refuelling • https://fuelcellbuses.eu/projects/newbusfuel
Training	• "Training for Work on Vehicles with High Voltage Systems"(DGUV Information 200-006), published by Deutsche Gesetzliche Unfallversicherung (DGUV, statutory accident insurance in Germany), Berlin, April 2012 https://publikationen.dguv.de/regelwerk/dguv-informationen/904/training-for-work-on-vehicles-with-high-voltage-systems

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 and Table 4-7).

As mentioned in Chapter 2, it is important to plan for the need for hydrogen backup supply. Such a backup option is of particular importance during the Commissioning and Initial Operations sub-stage. Having this in place means that test runs of the buses can be carried even when completion of the regular HRS is delayed. Backup fuel supply can also be important during Regular Operations.

Bus operators 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 4-8 highlights the importance of safety in the operation of FCBs and Table 4-9 provides resources in this respect.

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>

Technical Issues/Faults

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 System

- FC stacks: water leak
- FC drive system e.g., battery problems that led to reduced speed, especially on hilly routes

</td><td>

- Expect and be prepared to overcome faults
- Testing phase should be adequate for new technology and the planned work cycle and route. Once the bus has passed this phase, they should perform equivalent 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

Bright Idea: Close the Feedback Loop

One site made the following suggestion:
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 Challenges that have arisen include: • Data collection software don’t all deliver the operational data required • No access to CAN Bus data • Faulty data logger and no authorisation for the data logging dashboard, so that possible data issues could not be checked • Not all of the required data in the dashboard available • Dashboard wasn't ready at the beginning of operations • Poor WiFi connections	• Find out early about the most useful data collection software (and prescribe an adequate system in your tender documents) • Aim for one system for all buses, otherwise you may have different systems / dashboards with different data point availability for every individual supplier. • Make sure that the data system can be integrated with other operational systems, such as depot planning. • If data availability and provision is not adequate, keep the final retention payment until this is resolved • Be in regular contact with the relevant person who has to do updates or swaps of the data logger and chase them early
Technology Performance • Different starting process of the FCBs compared with diesel buses • New symbols and (error) messages at the driver-dashboard	• Adequate training of drivers • Have the appropriate expertise on hand to answer queries

Table 4-7: Commissioning and Initial Operations: Refuelling – Challenges and Best Practice Solutions.

Challenges	Best Practice Solutions
Technical Issues/Faults HRSs as of 2021 are still not standardised or fully mature. Operators have encountered a wide range of challenges, including: • Component failure • Software failures • Safety check failures • Noise (chiller) and leakage issues • Clear need for backup plan for refuelling	• Testing the refuelling process in slow and careful stages • Using contract requirements to ensure ongoing technical support from supplier • Check the H2 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. • Having and using backup refuelling arrangements • Ensure there is an adequate monitoring system on the HRS with quick response to alarms – specify supplier's response time to problems in hours.
Maintenance • Lack of local maintenance expertise and slow response time from supplier to fix issues	• Maintenance agreement should include: ➢ 24/7 service hotline ➢ remote access to the HRS ➢ local support (incl. flying doctor) ➢ Training of local technicians to support maintenance
HRS – Bus Interface challenges • Communications • Pre-cooling	• Communication between bus and HRS is important to ensure quick and complete fills. If there is no data transfer between bus and HRS, a more rigorous/conservative fuelling protocol needs to be followed to ensure safe refuelling while slowing down the filling process. • While pre-cooling is still being standardised, one site – in cooperation with the HRS manufacturer – has reconfigured refuelling schedule to avoid the need to pre-cool as much as possible (at a reduced speed of refuelling).
Data Logging • Accessing data on refuelling has not always gone smoothly	• 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 4-6: Hydrogen dispenser at Peizerweg Depot Groningen, The Netherlands.
This photo shows the second dispenser in front of the washing hall, from a different angle than Figure 4-2. The other dispenser is hidden by a refuelling bus. Photo by permission of Klaus Stolzenburg/PLANET.

Table 4-8: Commissioning and Initial Operations – Safety in Operations.

Safety in the operation of FCBs– see also Planning and Procurement in Chapters 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. Despite that, there has been a recent case of an empty FCB being involved in a fire. This event is being thoroughly investigated and will be publicly reported. 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. Safe operating protocols must always be observed and constantly reviewed. JIVE sites have prepared their own 'Hydrogen Safety Plans' from information freely available. **Generally speaking: Good Training and Maintenance = Safe Operations** *See also Resources in Table 4-9. Numerous commercial bodies can also advise on Hydrogen Safety in Transport.*

Table 4-9: Commissioning and Initial Operations – Useful Resources.

Area of Interest	Resources and where to find them
Safety	• https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects.pdf • 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: ➢ Simple template for a safety plan Interim publishable version ➢ Safety Planning Implementation and Reporting for EU projects ➢ Statistics, lessons learnt and recommendations from the Analysis of the Hydrogen Incidents and Accidents Database (HIAD 2.0) • "Wasserstoffsicherheit in Werkstätten "(DGUV Information 209-072, in German), 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
Hydrogen Safety Myths (2017/18)	• https://blog.ballard.com/hydrogen-safety-myths
JIVE Projects Safety Resource	• Hydrogen Safety Kit https://www.fuelcellbuses.eu/publications

4.3 Sub-Stage: Regular Operations

This sub-stage considers the regular operation of the Buses and the HRS/H2 supply as a combined system. At the time of collection of the information in this Chapter (August 2021) only 4 sites had started Regular Operations. These sites have reported few issues in transitioning to this phase. They were generally pleased with progress.

Their reports 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 to 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, corresponding to 8 min for 24 kg H_2
- Acceptable levels of availability and reliability of FCB and HRS operation

Nonetheless, there are still challenges being faced. These are reported below.

Table 4-10: Regular Operations of FCBs – Challenges and Best Practice Solutions.

Challenges	Best Practice Solutions
Communications • Managing expectations, primarily of PTO and ensuring they are aware that this is new technology and may not always be as close to perfect as are diesel buses • 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) • PTO should continue regular communications with the bus manufacturer • Share experiences with other operators that operate the same type/brand of buses
Maintenance / Repairs / Faults • Slow fault finding on bus issues initially. • Drivers misdiagnosing faults initially • Long downtimes due to longer delivery times for spare parts, in particular conventional parts (doors, mirrors, panes of glasses etc.)	• Keep some conventional buses in reserve perhaps longer than planned at the beginning of the project. This is in order to cover the 'teething' period with early arrival buses • Involve maintenance personnel in carrying out vehicle acceptance checks, so they learn details and issues early • Utilise manufacturer's predictive software to predict faults before they arise • Ensure a small stockpile of conventional spare parts at site (see recommendation in Table 4.2)
Data Collection • Data gathering is still an issue and not all data points are available • 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)

Table 4-11: Regular Refuelling Operations – Challenges and Best Practice Solutions.

Challenges	Best Practice Solutions
On-site H_2 Production Unit Performance (where in place) • Recurring electrolyser issues (e.g., power system unit, electrical transformer, water leakage) **H_2 Refuelling Unit Performance** • Refuelling slower than contractual agreement despite pre-cooling • Compressor maintenance issues • Failed refuelling (not meeting specifications for minimum bus tanks pressure/desired state of charge and/or for the maximum duration of a fill)	**Performance** Detailed fault-finding session with HRS supplier to determine faults and fixes for them

5 Bringing it all Together: Case Study in Best Practice

It is difficult to put together a summary of a series of Best Practice suggestions for deploying this new technology. What do you re-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 chapter provides a Case Study of what a Best Practice demonstration project might look like. The ‘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 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.

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 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.

The Context

The year is 2021 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 2023 onwards. As part of the region’s decision to develop a hydrogen-based energy system, 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 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 PTOs operating 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 in the early months of the project.

Understanding the Context / Clarifying 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. H_2 as a buffer for intermittent renewable energy)

- The chance to create synergies with local/regional/cross-regional industry (manufacturers; gas suppliers etc.; by-product H_2 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 Support

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

A Stakeholder Map was drafted and kept up-to-date during the following 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 stakeholder communication

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 dialoguing with interested PTOs.
- 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 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 Stages 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.

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; 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

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.

FCBs were compared with BEBs and internal combustion engines (diesel and natural gas). The intent was to make the case for FCBs outright, on the grounds of cost, operations and synergies with other regional hydrogen use options.

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 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 H_2 fuel supply at a fixed price.

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 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 included in the cost estimation decision process.

OPEX: The volume of H_2 required was to be augmented by assuming conversion of city administration's fleet of cars, refuse collection trucks etc. 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 TCO), 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.

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
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.

Developing the HRS Tender

The HRS tender, including H_2 supply, 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 (within one kilometre of the bus depot) 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 visit the proposed HRS location.

Developing the FCB 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.

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 are 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.

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

4. Deployment and Operations Stage

Deployment

Once the procurement contracts were signed, the project leader focus turned 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 contract. Some buffer was built into the timelines to manage any delays and also the expectations of all stakeholders.

Due to high demand the FCBs were not projected to be delivered for 12 months. The HRS was contracted to come online ahead of the buses to allow for a slow ramp up of the equipment.

HRS

A "hydrogen as a service"[4] supplier had been chosen for the HRS and a location site already identified prior to selecting the supplier. 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.).

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. A lot of the thinking work on this had been done by the project leader 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

Having been an integral partner in the project, 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.

[4] In this model, the FCBs simply turn up at the HRS and are refuelled. The PTO does not have responsibility for any of the refuelling infrastructure other than contracting and determining location.

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)
- 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.

Commissioning and Initial Operations

Despite every effort to synchronise the commissioning of buses and the HRS, the latter was delayed due to permitting issues. Back up 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. 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.

Bus data delivery systems specified by the contract were tested and found to be adequate to the needs of the PTO. 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 feedback on identified faults.

HRS Commissioning and Testing

Despite the delays with the refueller already experienced, the project leader ensured that the HRS supplier followed the planned slow 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 H_2 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.

Refuelling times were verified and found to be adequate with the pre-cooling in place.

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 back up diesel buses to be available should the FCBs have operational problems. These were accessed a couple of times due to driver concerns about dashboard messages suggesting malfunction of an FCB. All were found to be software issues and remedies 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.

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 were highly satisfied with the fuel efficiency, the reliability and the reception of the buses by the public.

The HRS was not as reliable as the buses and suffered numerous shutdowns during the first 6 months period. These situations were mitigated greatly by the contractual backup hydrogen delivery service.

Further important points to note from the story:

20. Rigorous planning (including contingency planning) and contractual comprehensiveness will avoid or mitigate most of the typical challenges experienced in the Deployment and Operations phase
21. Unexpected challenges will be easier to handle by building buffer into your timeline for starting operations. You must expect delays
22. Have back-ups 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
23. **Good Training and Maintenance = SAFE Operations**
24. 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.

6 Issues to be Addressed to Support Future FCB Deployment

The gathering of Best Practice information from the participants in the JIVE and JIVE 2 projects has produced a number of insights on how to support the uptake of FCBs. Given that there will be no more FC bus demonstration projects 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 newly created 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 recently revised CVD 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 recently, this market is still considered far from mature. There are still few FCB suppliers, and some of them are relatively small bus suppliers with limited financial resources. Many of the larger European manufacturers are not yet active in the FCB market. The result is that there is limited competition among FCB bidders.
   Few suppliers currently offer an articulated FCB although there is promise of others soon 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, particularly for small numbers of buses, and tenders with complex specifications and options, have not prompted any bids at all. It was hoped that tendering larger bus orders, including by means of Joint Procurement, would stimulate the industry. However, industry has not been quick to respond, and it is possible that the orders are still too small to attract additional manufacturers into the market.

3. Additionally, there appears to be very little uptake of FCBs in the EU 13 countries. 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 now will remedy this situation to some extent.
4. This lack of penetration into the markets in the East of the Union is being exacerbated by the imperative of the Clean Vehicle Directive targets unsupported 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 these.

Further financial support is needed and could, as an 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 3 & 4 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."

   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 as part of their JIVE/JIVE 2 participation. It is also be undertaken by Hydrogen Europe and by locally 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 monies 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 projects with little understanding of what they are embarking on.
   A one-day introductory, mandatory workshop before any city or region new to FCBs can submit an application for funding/finance could ensure that there is a basic level of insight and reduce the risk of local projects 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 PTAs/PTOs have become better at tendering appropriately, standardisation of HRS outcome specifications is urgent. 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.
9. A definition for Green H_2 that is widely accepted, or even EU endorsed, is urgently required. Some participants in JIVE projects believe that this definition should also acknowledge that the use of by-product H_2 that would otherwise be vented can be considered Green, or at least clean.
10. Permitting and certification of HRSs and bus maintenance workshops is making progress. However, it can still seriously slow down the implementation process.
11. Many of the above concerns have been successfully addressed on many occasions in close to 20 years of FCB demonstration in Europe. During this time various consultants have gained excellent insights and knowledge which could be accessed to effectively address such challenges. Developing a Register of these consultants and

their claimed experience and expertise would be a useful resource for new project participants.

Annex A Quantitative Expectations for Performance

Suppliers and customers of FCBs and HRSs have repeatedly stressed the major benefits of technical specifications being described as expected outputs rather than inputs. While this may seem challenging for a new technology, operators are generally very familiar with what services and performance (outputs) they need from their buses. 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 overnight refuelling window and a maximum time to fill per bus, rather than requiring a certain size for the HRS on-site storage.

To help focus JIVE and JIVE 2 project partners on this, and to have them clarify their expectations for performance, they were asked early to quantify these with respect to a set of parameters. This Appendix provides an aggregated overview of the responses.

Expectations were collected on the following topics:

- Availability of HRS and FCBs
- Cost of hydrogen and bus operating costs
- Acceptable wait time for repairs
- Time to fill a bus
- Specific fuel consumption
- Fuel cell stack lifetime

Methodology of evaluation

The responses of the JIVE and JIVE 2 Local Coordinators were evaluated by calculating:

- the lowest and highest values
- the median (the centre of a dataset)
- the arithmetic mean (referred to as “mean” in the following)

When the mean and the median are similar or the same, the dataset is more or less evenly distributed from the lowest to highest values. The median helps eliminate the impact of outliers.

Table A-1 shows the lowest figure, the median and the highest figure for each of the above categories.

Summary

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

Table A-1: Quantitative Expectations for the Performance of HRSs and FCBs.

Parameter	Lowest / Median / Highest
1. Availability HRS [%]	90 / **99** / 99.9
2. Availability Buses [%]	80 / **90** / 99.9
3. Cost of hydrogen [€/kg]	4 / **6** / 12
4. Bus operating costs relative to standard fleet [%]	75 / **150** / 400
5. Maximum wait time for Repairs HRS [hours]	0 / **12** / 120
6. Maximum wait time for Repairs FCBs [hours]	2 / **24** / 72
7. Specific fuel consumption [kg/100 km]	8 / **9** / 12
8. Time to fill [minutes]	5 / **10** / 15
9. Fuel cell stack lifetime [hours]	7,000 / **25,000** / 50,000

1. Availability HRS

The expectations range from 90% to 99.9% availability.

The median value is 99%. This is in line with the work programme targets (with downtime for scheduled preventive maintenance excluded).

HRSs in the CHIC and HyTransit projects have proven that availabilities above 90% are feasible. However, making a HRS supplier guarantee 99.9% on a 24/7 basis would certainly result in extra costs for a very high level of redundancy and maintenance capability.

2. Availability FCBs

The expectations range from 80% to 99.9% availability. Again, median value of 90% is in line with the project targets, which are to reach more than 90% after an initial six-month ramp-up phase. The highest expectations of 99.9% do not appear to be reasonable given that only one site in the previous CHIC project achieved the 85% availability target for that project. Few suppliers would guarantee such a level of availability even for diesel buses.

Achieving the JIVE/JIVE 2 project availability target for the FCBs seems to be more challenging than reaching the project availability target for the HRS.

3. Cost of hydrogen

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

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

4. Bus operating costs relative to standard fleet [%]

The JIVE and JIVE 2 targets are to achieve a maximum of 200% of what is required to maintain an equivalent a diesel bus, aiming at 150% by the end of the project. The median is in line with this, but some sites expect much better figures.

5. Maximum wait time for repairs of the HRS

Achieving the median figure of 12 hours will require very good support from the technology suppliers. Wait time for repairs was not analysed in previous projects, but it is clear that 12 hours was not achieved in most cases.

6. Maximum wait time for repairs of the FCBs

Again, achieving the median figure of 24 hours will require good support from the technology suppliers. Wait time for repairs was not analysed in previous projects, but it is clear the median value was not always achieved.

7. Specific fuel consumption

The median figure of 9 kg/100 km is 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 is 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 HyTransit 10.7 kg/100 km on average.

8. Time to fill

The JIVE projects have targets for speed of dispensing rather than time to fill. The intention is 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 to be dispensed. At 3 kg/minute this would take 10 minutes and be in line with the median expectations of the sites.

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

9. Fuel cell stack lifetime

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

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

Project coordination:

elementenergy
an ERM Group company

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Hydrogen Europe

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