JIVE (D3.34) | JIVE 2 (D3.5)

Best Practice Guide for Fuel Cell Bus Maintenance Workshops

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ZERO EMISSION

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List of Abbreviations and Terms

ATEX	ATmosphères EXplosibles, often used in connection with two EU Directives concerned with explosion-proof equipment (e.g. 'ATEX lights') and e.g. classifications of hazardous places ('ATEX zones'), see section 2.1.
bar	Unit of pressure. One bar is about the same as the air pressure at sea level on earth.
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
CHIC	Clean Hydrogen in European Cities, project co-funded by the Fuel Cells and Hydrogen Joint Undertaking under the 7th Framework Programme (2010 – 2016)
DGUV	Deutsche Gesetzliche Unfallversicherung; German Statutory Accident Insurance
EU	European Union
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)
H_2	Hydrogen
HRS	Hydrogen Refuelling Station
JIVE	Joint Initiative for Hydrogen Vehicles across Europe, project co-funded by the Clean Hydrogen Partnership under the European Union's Horizon 2020 Framework Programme (2017 – 2024)
JIVE 2	Second Joint Initiative for Hydrogen Vehicles across Europe, project co-funded by the Clean Hydrogen Partnership under the European Union's Horizon 2020 Framework Programme (2018 – 2025)
LEL / LFL	Lower Explosive Limit / Lower Flammability Limit (synonyms; see section 2.1)
TUV / TÜV	Several companies and associations which conduct inspections and certification of technical equipment and services to minimise hazards
UEL / UFL	Upper Explosive Limit / Upper Flammability Limit (synonyms)

1 Purpose of these Guidelines

Increasing numbers of local and regional governments are requiring public transport bus operations in their jurisdictions to be locally emission free. At the minimum, they have to comply with the Clean Vehicles Directive of the European Union. Fuel Cell Buses (FCBs) running on hydrogen are one option that can achieve this outcome. The safe, efficient and effective maintenance of these buses is essential.

The potential complexity and cost to construct new, or upgrade existing, vehicle maintenance facilities to accommodate FCBs can be a significant factor for whether an operator chooses to bring this technology into the fleet. Of course, additional costs are not confined to the introduction of FCBs into a fleet. Introducing or changing over to any other motive system, such as battery electric buses (BEBs) will also incur additional costs.

This document provides guidelines for implementing FCB maintenance workshops, including associated safety aspects. The absence of guidelines has been highlighted by JIVE and JIVE 2 project partners. The document largely builds on, and makes publicly available, knowledge gained through JIVE and JIVE 2. It combines published technical information with real world experiences to provide an overview of what is involved in establishing a maintenance facility for FCBs. The purpose is to guide organisations which are new to FCBs through the decision-making process for new facilities and depot upgrades. The guidelines start from the assumption that little to no knowledge is held by the readers regarding the procedures required for maintenance of FCBs.

- Section 2 introduces the risks to be addressed when maintaining FCBs, and explains the main steps to be taken when implementing a dedicated workshop.
- Section 3 presents details from two project sites.
- Annex A provides an outline of JIVE and JIVE 2. For a broader overview of the projects and FCBs in general, the https://www.fuelcellbuses.eu/ website is a good starting point.
- Annex B contains references and further resources.
- Additional information on risks and mitigation measures can be found in Annex C.

These guidelines provide an insight into how to approach implementing a maintenance workshop for FCBs. However, it is not possible to identify requirements or regulations for individual facilities, as national frameworks and local conditions will vary.

2 Implementing a Maintenance Workshop for Fuel Cell Buses

Safe, efficient and effective maintenance of any buses in a public transport fleet is essential. Knowing, understanding and managing the risks, will ensure that deploying and operating FCBs, including a dedicated workshop, can run smoothly.

2.1 Risks Related to Servicing FCBs and Risk Mitigation Measures

- Flammable mixtures of hydrogen and air
  Pure hydrogen is not flammable, but mixtures of hydrogen and air are. On board the buses, hydrogen is contained in a closed, gas-tight system, so normally no flammable mixtures occur. Hydrogen is much lighter than air and escaping gas will rise and disperse quickly outdoors. However, in enclosed spaces hydrogen that escapes accidentally can be trapped, typically under the roof, and aggregate. This means that a maintenance workshop needs to be monitored for hydrogen releases and mitigation measures implemented to remove the gas from the building before an ignitable concentration of hydrogen in air is reached, thereby avoiding the risk of an explosion.

Explosion

In simple terms, an explosion occurs when heat from a chemical reaction cannot dissipate quickly. This means that the temperature increases further, accelerating the reaction and raising the temperature even more. The pressure will also increase resulting in a blast wave. Therefore, an ignition or a fire can cause an explosion, particularly in confined spaces.

Flammability Limits / Explosive Limits

Mixtures of between 4% and 75% of hydrogen volume in air are flammable. Therefore, hydrogen's Lower Flammability Limit (LFL) is 4% and its Upper Flammability Limit (UFL) is 75%. The terms Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL) mean the same, and are more commonly used.

- High-voltage equipment
  Fuels cells and batteries are high-voltage devices. Maintenance personnel need to be protected from suffering electrical shock.
- Sparks
  Sparks can ignite a flammable mixture of hydrogen and air. Sparks can come from

many sources such as electricity, metal tools, or 'hot work' such as welding, and measures need to be taken to avoid sparks.

- High Pressure
  The hydrogen is stored at high pressure. The usual measures when dealing with pressure vessels need to be applied.
- Working on vehicle roof
  Depending on the bus manufacturer, FCBs can often have components, such as hydrogen vessels or batteries, located on the roof. If so, appropriate equipment for safe working at height needs to be in place.

There is an EU directive that prescribes the minimum safety requirements for workplaces with potential risk from explosive atmospheres, often referred to as 'ATEX workplace directive', with ATEX standing for 'ATmosphères EXplosibles'; see Annex B for full reference. It includes classifications of hazardous places. The definition of Zone 2 reads: "A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only." Given this definition and the arrangements for FCB maintenance facilities, Zone 2 will be the typical ATEX classification of the maintenance area for such vehicles.

A second EU directive, often referred to as 'ATEX equipment directive' deals with equipment and protective systems intended for use in potentially explosive atmospheres. Equipment in line with this directive is often labelled 'ATEX', such as 'ATEX lighting'.

More information on risks can be found in Annex C.

Generally, of course, it is important for workplace safety to be addressed thoroughly and holistically with respect to equipment that supports risk mitigation, management processes, and appropriate staff training. The individual risks, safety procedures and overall management must be considered in totality and not in isolation, with particular attention being paid to how some risks might interact.

2.2 Main Steps

Figure 2-1 visualises the main steps when implementing a workshop for FCBs and links them to the related sub-sections in this document. In practice, taking these steps will not be a linear process but individual steps overlapping, and some steps possibly being repeated as more information becomes available.

Figure 2-1 also indicates that many of the steps, therefore many important decisions, take place *early* in the process.

The key question of whether to modify an existing facility or build a new one may already be decided at the beginning of the project. When there is not enough space to erect a new building for FCB maintenance, an existing unit will need to be upgraded. On the other hand, if the FCBs expand the fleet rather than replace other vehicles, additional maintenance capacity may be required needing an additional building or an extension. When the matter is not predetermined, however, a careful analysis is recommended, considering both options as part of the other steps during the Conceptualisation stage.

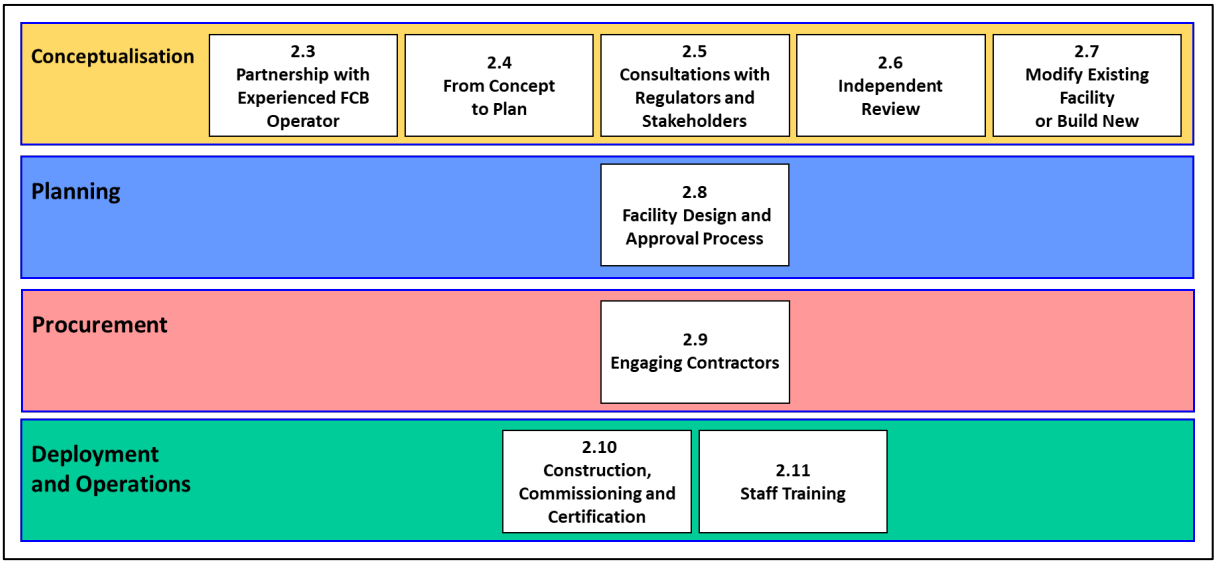

Figure 2-1: Four Stages Incorporating Nine Steps to Take when Implementing a Maintenance Workshop for FCBs.
Grouping of the steps is in line with the stages approach of the JIVE/JIVE 2 Best Practice Report (see Annex B).

2.3 Mentoring Partnership with Experienced FCB Operator

Establishing a mentoring arrangement with an operator who already has a fleet of FCBs and a functional maintenance facility can provide significant immediate and long-term benefits. The mentor will have been through all the processes and activities and is likely to be able to give timely and targeted advice on planning and implementation actions.

Mentoring relationships with one or more operators can be developed from site visits. Such visits can allow a wide range of issues to be discussed and first guidance provided. This can include other matters such as vehicle performance, hydrogen supply options and the Hydrogen Refuelling Station (HRS).

2.4 From Concept to Plan

A maintenance facility concept can be developed based on the learning gained from site visits. This concept should take account of any known constraints and future requirements. These might include:

- Available space for a new maintenance facility structure,
- Adjoining community and infrastructure outside the depot with safety or public concern issues,
- Future fleet plans and future depot plans,
- Likely costs and availability of finance, perhaps including external financial support,
- Other activities and contracts likely to impact implementation.

This initial concept and list of constraints and requirements will help identify uncertainties or blind spots.

The concept should be reviewed and refined, keeping in mind the context of, and linkages to, the other steps of the Conceptualisation stage as shown in Figure 2-1. In this way, the project plan can be progressively developed. It will have to cover the following elements in particular:

Activities and Timeline

The project plan, particularly the timing of the various elements, needs to be aligned with the overall FCB fleet deployment: It is highly desirable for the vehicles and the maintenance facility, but also for the HRS and hydrogen supply, to become available and fully operational as close to the same time as possible. From the longest lead time, possibly the implementation of the HRS, the timeline can be developed backwards, and actions can be allocated to appropriate dates, and milestones can be set. Figure 2-2 provides an indicative example.

Responsibilities and Accountabilities

Activities need to be broken down into tasks. The responsibility for carrying them out can be allocated to a person or an organisation. This list is likely to include both internal staff, as well as people and organisations external to the organisation.

It is important to also identify where the accountability lies for each action to be completed, and the accountable person or organisation understands their role.

For example, while the responsibility for carrying out bus maintenance items might rest with a specific technician, the accountability to ensure that is undertaken properly is likely to rest with a manager. The manager must ensure that the task is completed as required.

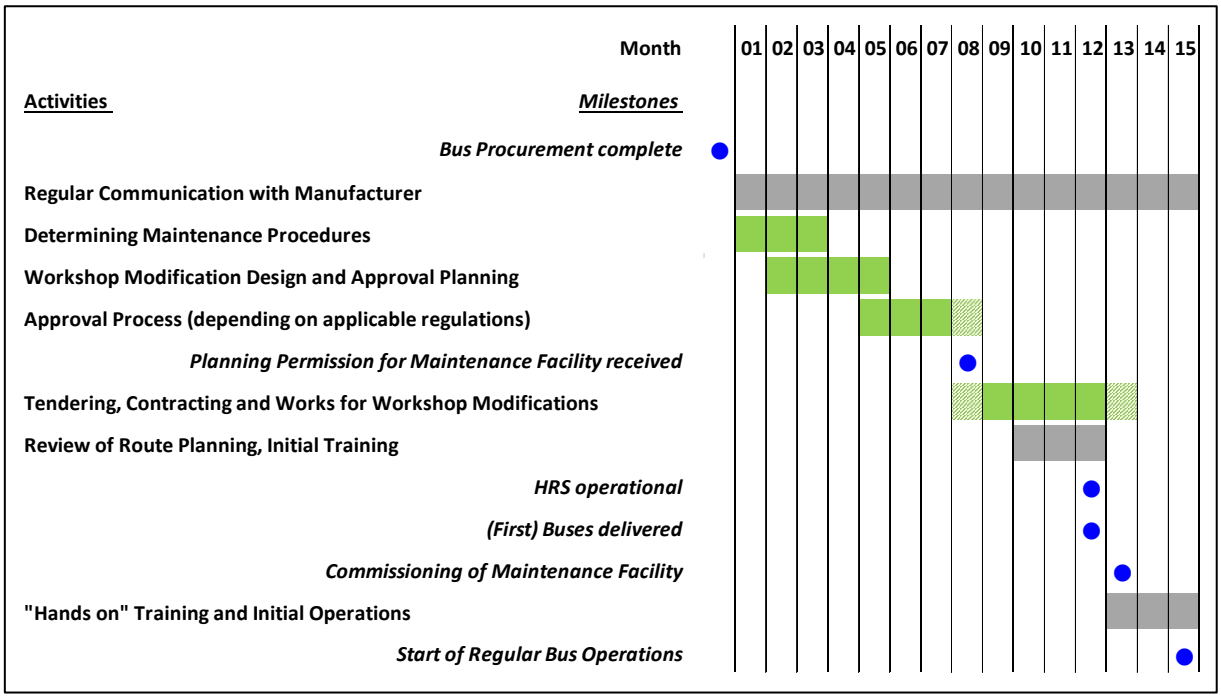

Figure 2-2: Indicative Timeline for the Deployment Stage of Modifying a Maintenance Workshop. Blue dots stand for selected important milestones. Green cells represent activities concerned with workshop modification, grey cells represent related activities as part of the overall process of FCB implementation. The chart indicates that, once a concept has been developed, it can take up to a year from design to commissioning. When permits are not required, the period can be shorter, see the Case Studies in section 3.

If external consultants are responsible for undertaking a task, the accountability for ensuring that it is completed will rest with an internal manager. Sanctions may be linked to the responsibility and accountability framework, and it is important that these are reasonable, and able to be implemented.

The explicit separate identification, documentation and communication of responsibilities and accountabilities is an important part of the project planning and management process. Failure to do this is often one of the root causes of projects not progressing as planned.

Cost Elements

The investment costs will depend on a multitude of factors. A mentor or other FCB operator is likely to be prepared to share detailed information. Focus should be on items likely to be the most expensive, and items likely to have the most volatile cost variation.

Costs will vary between countries, local industry conditions and regulations, and other factors. The only way to be sure of the likely costs is through quotations.

The CHIC project published a report in 2015 with a summary of likely investment costs. While the report is nearly ten years old and therefore the actual cost numbers cannot be relied on, Table 2-1 taken from that document does provide some *first* guidance as to the type of cost items to be considered.

Two more recent real-life examples with the approximate costs of €155,000 and €280,000 for implementing JIVE maintenance facilities, deployed in 2020 is presented in section 3. In both cases, an existing facility was modified with different measures taken.

When a new building is erected, the investment can be approximated by assuming the costs for a conventional workshop plus, at the very maximum, the cost for conversion measures.

Table 2-1: Indicative Investment Costs of Equipment or Modifications Needed to Service FCBs. From 'Analysis of investments in workshops for fuel cell buses and hydrogen refuelling stations', Lozanovski, A and Ko, N; Deliverable 3.11, 2015. Based on input from several sites in different countries during the FBC demonstration project CHIC, 2010 – 2016.

Part	Investment cost [€]
H_2 specific incremental investment cost for workshop equipment per bay: A) Retrofitting under ideal conditions (some existing components like existing ventilation and/or ATEX electricity)	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
Changes to the workshop structure Extra windows or fire protective doors	5,000 to 15,000
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
Power outlet for overnight power supply at parking space	1,000 to 1,500 per power outlet

2.5 Consultations with Regulators and Stakeholders

Regulations and Regulatory Bodies

Early in the planning and preparation process, and before any formal permitting process, a number of activities are recommended:

- Identify the relevant key regulatory authority;
- Identify relevant regulations, standards and requirements, and impacts, in line with the risks to be managed outlined in Section 2.1 and Annex C; several of the resources listed in Annex B can be of help;
- Contact and discuss the project with the key authority, establish approval timelines and identify contacts with other regulatory authorities that might be involved;
- Align the facility concept with the findings.

Obtaining approval for a FCB maintenance workshop may appear to be straightforward at first, particularly if it seems that only a building permit is needed. However, it can turn into a lengthy and resource-consuming activity.

The process to establish a new FCB maintenance workshop is likely to be similar to establishing a workshop for diesel buses, but, in the best case, with some relatively minor additional requirements. However, in some jurisdictions there may be different regulations applying to new constructions compared to modifications of existing ones. For example, this is the case for fire regulations in the Netherlands (see 'Fire Protection in Depots' in Annex B).

Regulatory requirements for modifying an existing facility may be quite reduced. Experience suggests no additional permits may be required for modifications, see the Case Studies in section 3. However, it is essential to hold discussions with relevant regulatory bodies to confirm compliance.

Specific regulatory arrangements are likely to be different from place to place. This includes which authority has responsibility for which area of activity in the project, as well as what is regulated and the details of the regulations. The order with which different regulators can consider matters, and which approvals have priority can also be important.

Local authorities typically have not had much experience dealing with hydrogen generally, especially hydrogen as a fuel for mobility. Due to inexperience, they may tend to impose overly strong measures. Therefore, the overarching principle is to establish and maintain strong relationships with the regulators, and communicate clearly, consistently and as early in the process as possible.

The relationship between the FCB project leader and regulators can be developed as one of 'mutual education'. The regulator gets to understand the technology and associated operating procedures, while the FCB project leader learns about the local view on relevant regulations and procedures. Joint site visits to operational FCB fleets or a representative of the mentoring FCB operator explaining their experiences can be productive.

While not part of formal regulatory processes, the insurer of the depot also needs to be involved.

Other Stakeholders

As part of the overall process of implementing FCBs, it is useful to consult with other stakeholders as well, including:

- First responders, particularly the fire brigade if they have not been part of the regulatory input;
- Surrounding residents and businesses;
- Interested parties such as public transport users and environmental groups.

Investment of time and effort into this early stage of the project will pay dividends. Community acceptance of the overall FCB strategy and the planned activities can be essential to smooth and easy project implementation.

There are useful resources to address this matter, in particular the JIVE/JIVE 2 Best Practice Report 2024 (see Annex B).

2.6 Independent Review

Engaging an independent, third-party auditing and verification provider to work alongside the internal project team throughout the design, construction and implementation stages can be useful. For new facilities, they can review the proposed site and design. For modification of existing facilities, they can provide a review and recommendations for the design. It can be very useful for them to be engaged early in the planning process.

At the end of construction, the independent reviewer can check safety systems, and provide certification which can be used with regulators (section 2.10). This will also provide reassurance to other parties, including staff and insurer.

Depending on the context, an independent review may be mandatory to obtain permits.

2.7 Modify Existing Facility or Build New?

As touched upon above, the question of whether to modify an existing facility or build a new one may already be decided at the beginning of the project.

For example, constructing additional maintenance capacity may have been decided due to a general enlargement of the fleet. Also, if there are already considerations for longer term options for a larger FCB fleet, then this additional maintenance capacity might include constructing a new facility for FCBs. However, if current plans only extend to a first demonstration project, this will likely lead to a preference to modify an existing facility.

Various other factors can also impact on the decision. They need to be identified early during the Conceptualisation stage and relevant information established step by step. Such factors might include:

- Finances available;
- Suitability for any part of an existing building to be modified, e.g. an existing maintenance bay or a former washing hall;
- Footprint availability on the depot;
- Time frame when the facility will be required;
- Depot owned or leased.

2.8 Facility Design and Approval Process

Planning of the facility or planning for its modification will be based on the information collected and assembled in the project plan during the Conceptualisation stage. It will also depend on information provided by bus manufacturers about their maintenance requirements. This means that final facility design might only be possible once the FCB provider has been selected and full information about the FCB is available.

The design process is governed by two over-arching objectives:

- Facilitating the efficient, effective and safe maintenance of the vehicle, including both the conventional bus components, as well as the FCB specific components and procedures; and
- Mitigating the particular risks associated with servicing FCB via appropriate design features.

The latter is the focus in the following.

Facility construction

- Appropriate ATEX zone definition/classification within the facility and signage;
- Explosion proof, ATEX rated equipment, connections, lights and power outlets, in particular any electrical items that cannot be switched off and isolated in case of a hydrogen alarm;
- Hydrogen sensors and alarm system, to alert staff, initiate or increase ventilation, and possibly shut down any non-ATEX equipment, with usually two alarm stages (see Case Studies in section 3);
- ATEX exhaust ventilation fans in the roof to rapidly vent hydrogen-air-mixtures to atmosphere before flammable/explosive levels are reached; apertures in the wall or doors that open when alarm is triggered to ensure sufficient inlet air;
- Alternatively, modification of the facility ventilation system to increase air pressure in the building in case of an alarm and hatches in the roof that open, so that hydrogen-air-mixtures are vented through the hatches;
- Roof design to minimise spaces that might trap escaping hydrogen or slow down its removal;
- Mobile gantries or platforms to enable staff to work safely on the bus roof;
- Alternatively, stationary structures to enable staff to work safely on the bus roof;
- Vent lines to defuel a bus in a maintenance bay e.g. when accidental damage to the hydrogen storage system occurs or is suspected;
- Hoist to move components from/onto the bus roof;
- Static electricity dispersing capability of the floor and/or grounding points for the buses;
- Facilities for sorting and storing specialised tools and equipment required to work on the hydrogen, electrical and battery components and systems.

Mobile Equipment

- Antistatic clothing/shoes for workers;
- Hydrogen body worn sensors for maintenance staff;
- Hand-held ‘hydrogen sniffers’ readily available for each worker;
- Leakage spray;
- Spark resistant or ATEX hand tools, possibly powered by compressed air;

- Emergency response kit, including an insulated pole to rescue a person incapacitated from electric shock.

Procedures

After the design elements of the maintenance workshop have been developed, it is important to review and amend where appropriate the risk management and emergency procedure documents for the whole depot to account for the new situation. These will need to be continually updated as situations change.

Outside the Workshop Building

A safe outside open-air parking area for any vehicle with a suspected hydrogen leak or problem with a high-voltage battery needs to be designated, with enough safety distance to any source of ignition. The location must be clearly signed and kept clear and available only for these circumstances.

Resources for Supporting the Design Process

The design stage is key to determining the effectiveness of the facility, and ultimately the FCB fleet operations. It is important to use the many resources that are available, and build on the knowledge and expertise of previous work. There is no reason to start with a blank sheet.

Apart from specific resources, Annex B also includes general reference documents, such as a template for a safety plan provided by the European Hydrogen Safety Panel.

Internal and External Stakeholder Acceptance

The design process is likely to be iterative and require modification along the way as more information and understanding develops. Communication with regulatory authorities, internal units with oversight roles, and other stakeholders such as local communities should be continued throughout all planning activities.

Approval Planning and Approval Process

As outlined above, obtaining the required permits is best considered as an on-going process and not a single step. Consultation and collaboration with regulators, and the mutual education process will ease the path to a successful outcome.

For this reason, it is good practice to allocate time throughout the design phase to working with regulators, rather than a single time allocation at the end to submit documents for the formal approval process. In that way, approval planning and the formal approval process overlap, perhaps more than indicated in Figure 2-2.

2.9 Engaging Contractors

To implement FCB specific measures in a new workshop building or the planned modification in an existing one, competent contractors have to be identified and selected. As with all contracting, specifying the scope of works and the outcomes required is key to successful completion.

Here too, the mentoring partner can be of considerable assistance. They may be able to provide copies of documents specifying tasks for contractors, and inviting proposals. It may also be possible to obtain recommendations for competent contractors for specific tasks. Applicable tendering requirements need to be taken into account throughout these stages.

When taking this step, it can be important to involve the facility insurer again. In some cases, they may require that contractors installing or carrying out safety-critical tasks have specific certification.

2.10 Construction, Commissioning and Certification

Construction

The construction activities are likely to be undertaken by one or more outside organisations and contractors. As discussed above, specifying the tasks, the scope of work, and the required outcomes is key.

The people who will oversee and be responsible for the construction on behalf of the contractors must be identified and clearly understand the work and timelines. The communication and accountability links to the FCB project leader need to be clear and explicit.

Possible involvement of the independent certifier should be considered and clarified.

Commissioning and Certification/Permitting

Initial commissioning of the facility will require all the various risk management elements to be tested and verified. This will range from checking the operations of the various components such as hydrogen sensors/alarm systems, ventilators and vents, and gantries, through to the inventory of tools and other mobile equipment, and the facility documentation. The broader depot documentation also needs to be verified.

At the end of construction, an independent expert may be used to check the facility and provide certification. In some cases, this might be mandatory to obtain the final permit to operate.

Documentation and Maintenance Planning

All the design, planning and implementation activities must be documented. This includes formal documentation of the development processes, and, most importantly, the agreed risk assessments, mitigation measures and strategies, training and accreditation arrangements and review timelines.

This documentation needs to be regularly reviewed to make sure that it is appropriate for the circumstances existing at the time. That includes ensuring that the facilities and relevant staff are consistent with the documented infrastructure, training and accreditation, and the work processes being conducted.

Regular checks need to be conducted to ensure that the documents match the activities in the workshop. All staff should know how to access the documentation relevant to their roles.

Maintaining the new devices needs to be planned for and implemented.

2.11 Staff Training

A number of staff will be working in the workshop on and around any FCB. Some of the activities will involve working specifically on the FCB powertrain – hydrogen tanks, electrical drives, compressors, and balance of plant components. Most or all of these tasks will require staff to have specific technical training and skills. Levels of training may include qualification to work on conventional components of the vehicles only, on the gas system, on the high-voltage system when in isolated state and on the high-voltage system when not in isolated state.

There will also be other staff doing routine tasks on the depot who will need to be trained specifically, including cleaners and refuellers. All depot staff will receive some awareness training at least, in line with updated risk management and emergency procedures.

Requirements should be discussed with mentoring partners and with relevant regulatory authorities. It is essential that these arrangements are regularly verified and updated as necessary.

There are also likely to be visitors to the facility interested in seeing and understanding the technology, as well as the integration of FCBs into fleet operations. Arrangements for their safe conduct in and around the facility need to be documented and implemented, and their practice regularly verified and updated as necessary.

There are numerous education and training courses available relating specifically to hydrogen and also to hydrogen and electrical drives in transport. These are also likely

to be available in the native language of the maintenance staff. Samples can be found in Annex B.

3 Case Studies of Modifying Maintenance Facilities

This section outlines some key decisions and measures taken in the process of establishing FCB maintenance facilities in London and Wuppertal. Each of the two sites took different approaches to modifying an existing facility, and the information below can provide useful guidance.

As explained above, permitting requirements, and therefore involvement of regulatory agencies, are likely to be greater for establishing new facilities.

3.1 London

Table 3-1: Design and Implementation Activities for Modifying a Maintenance Workshop to be used for FCBs in London.

Area of Activity	Details
Decision 'modify or new' and reasoning	Modification of existing facility. Essential to keep costs down and timescale of the project did not allow to build new. Also, the property is leased. Be able to maintain diesel, diesel-hybrid, BEBs and FCBs in all bays to allow maximum flexibility. Facility: • 4 maintenance bays (Figure 3-1) for 20 FCBs. Bays can also be used for buses with other drive trains • Floor space about 610 m^2, height about 8 m, volume about 4,900 m^3
Role of authorities / permits needed	Consultation with the local council which did not require any permits for modifications to existing maintenance workshop; no neighbouring residential houses
Use of independent reviewer	• Assessment by TÜV, based on site visit • TÜV signed off after deployment, confirming their recommendations had been implemented • Second consultant provided emergency response plans and overall hazard management. Also, second opinion on safety infrastructure and suggested supplementary measures.
Timeline	About 6 months from design of modifications to operation
Main measures	• ATEX Zone 2 classification • Alarm system, see below • ATEX active venting system, see below • ATEX emergency lighting, battery based which provided similar effectiveness but at lower cost than hard wired

Area of Activity	Details
	• Signage (see Figure 3-1 and Figure 3-2) • Confirmed that floor meets electric discharge requirements → no measures needed • Grounding points for buses • No spark generating 'hot work' such as welding at the facility • Removal of gas oil heaters in the roof • Removal of fire loads (flammable substances) / safety clearance of 3 m around FCBs • Risk management plan and emergency response plan developed/amended and implemented • Training measures, see below Note: The double-deck FCBs in London do not have FC drive components on the roof.
Alarm system	• 4 hydrogen sensors at rear of the buses where hydrogen tank is located (Figure 3-2) • 4 hydrogen sensors along roof apex line (Figure 3-3)
Alarms	• 10% LEL: Ventilation activated (see below), heating switched off, beacons activated; roller shutter doors to be opened manually • 25% LEL: Sound alarms activated, electricity shutdown at fuse board, extractor fans continue working; building to be evacuated
Venting system	• 3 ATEX extractor fans in roof along apex line (Figure 3-3) with air exchange rate of 3 times workshop volume per hour when triggered by alarm (about 14,700 m^3/h) • 3 vent openings (non-ATEX) in the lower part of the external walls to allow air to be drawn in (Figure 3-4) • Manual activation possible but no manual de-activation
Training	• Hydrogen awareness training for all depot staff, particularly those working in the maintenance area • Dedicated trainings for the technicians doing maintenance/repair of the Hydrogen system • High-voltage training previously provided when diesel-hybrid buses introduced
Personal protective equipment	• Antistatic clothing/shoes • Hydrogen body alarm devices • Hand-held 'hydrogen sniffers' to check e.g. piping on board the buses

Area of Activity	Details
Quarantine / venting place outside the building	• Special open-air area for bus to be parked in case of a suspected hydrogen leak or damage to the hydrogen system or an unsafe battery state • 3 m safety clearance around parked bus within which no flammable substances and no sources of ignition to be stored within or above
Approximate costs	Approximately €155,000 in total, of which about • €48,000 extractors including electrical work • €35,000 hydrogen detection and alarm system • €28,000 new heating system (warmer air blowers, gas burner on floor and in sealed room) • €24,000 ATEX emergency lighting

Figure 3-1: Modified Maintenance Workshop in London / 1.
Two external views. Photos by permission of PLANET.

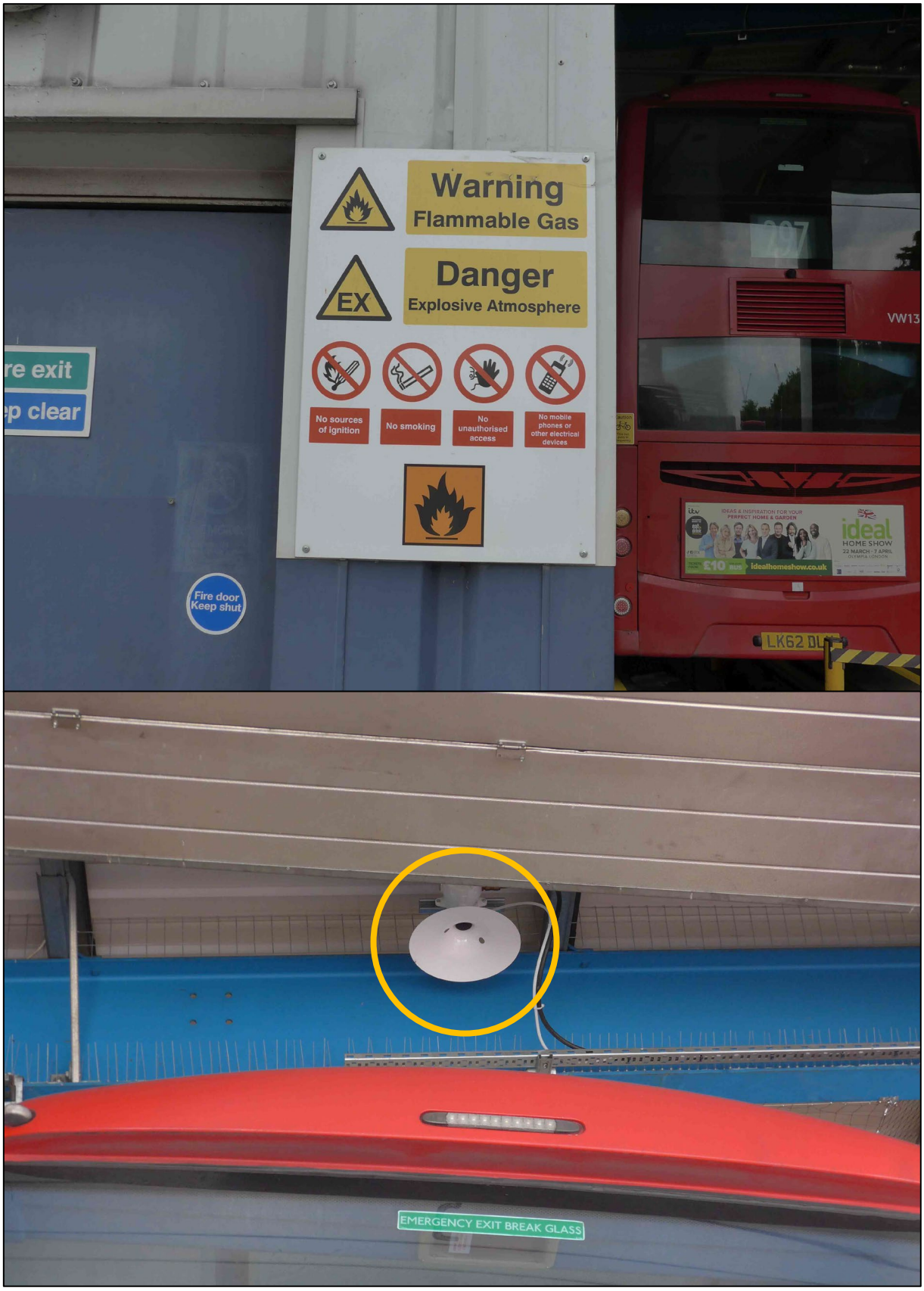

Figure 3-2: Modified Maintenance Workshop in London / 2.
Top: Signage on outside of workshop, Bottom: Hydrogen sensor above the rear of a bus (orange circle). Photos by permission of PLANET.

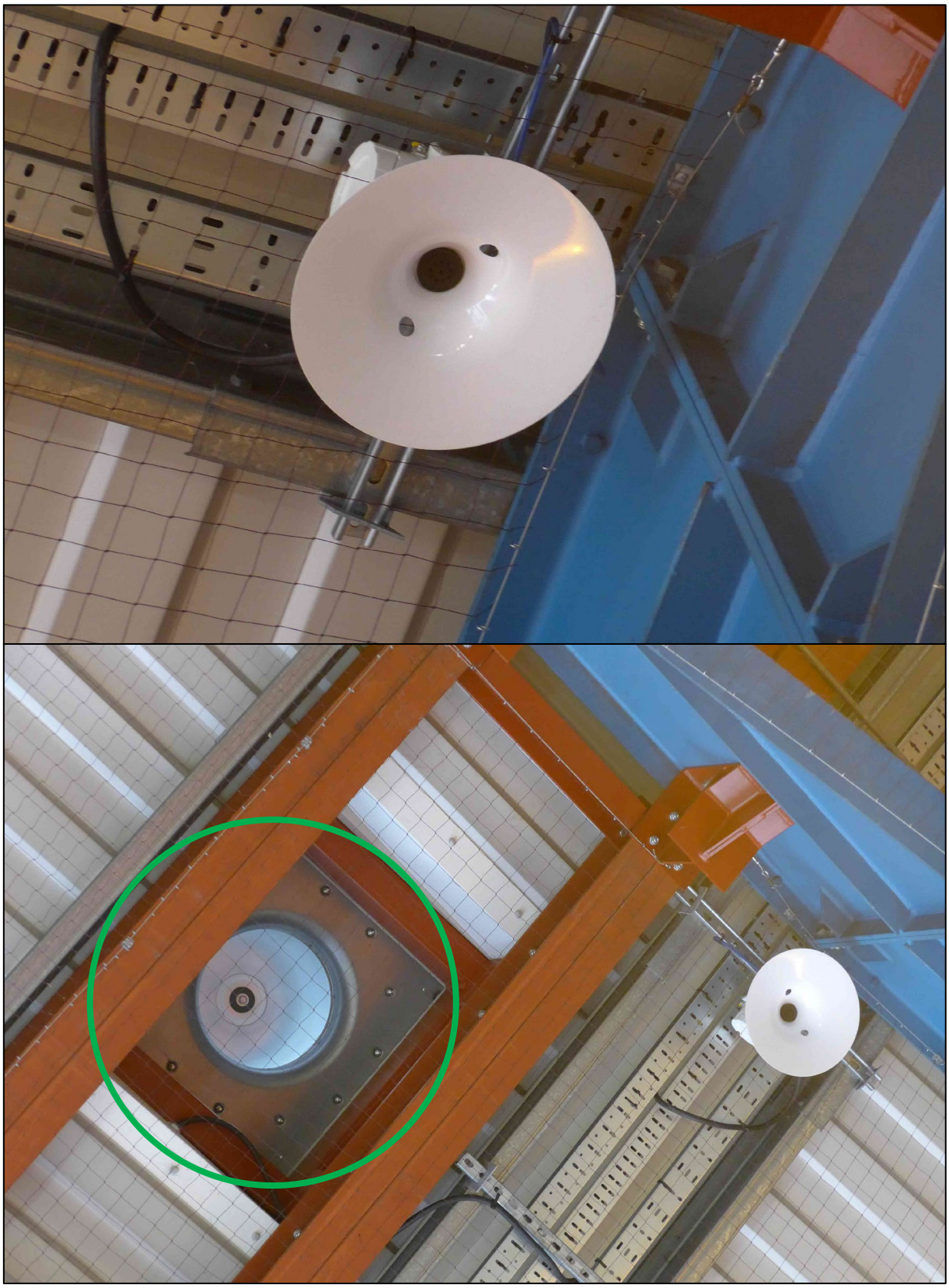

Figure 3-3: Modified Maintenance Workshop in London / 3.
Top: Gas collector (white) sourounding the hydrogen sensor in the black centre; Bottom: Extraction fan (left/green circle) and hydrogen sensor (right) at the roof apex.
Photos by permission of PLANET.

Figure 3-4: Modified Maintenance Workshop in London / 4.
Top: Ventilation grille in the external wall; Bottom: Inside view of air inlet with motor-actuated fins (currently closed), Photos by permission of PLANET (top) and TfL / Martin West.

3.2 Wuppertal

Table 3-2: Design and Implementation Activities for Modifying a Maintenance Workshop to be used for FCBs in Wuppertal.

Area of Activity	Details
Decision 'modify or new' and reasoning	Modification of existing facility. Essential to keep costs down and timescale of the project did not allow to build new. Be able to maintain diesel and FCBs in all bays to allow maximum flexibility. Facility: • 3 maintenance bays in separated area within larger workshop building (Figure 3-5 and Figure 3-6) for 20 FCBs. Bays can also be used for buses with other drive trains • Floor space about 520 m^2, height about 6.75 m, volume about 3,500 m^3
Role of authorities / permits needed	Consultation with local building authority → No permits required because no change in use (maintenance of buses continues)
Use of independent reviewer	Assessment by TÜV, a second consultant and internal health and safety officers, based on site visit → Agreement on minimum set of requirements
Timeline	• About 9 months to prepare the concept, including site visits and other information gathering • Subsequently about 9 months from beginning of planning to beginning of operations
Main measures	• ATEX Zone 2 classification • Alarm system, see below • Modification of venting system, see below • ATEX emergency lighting • Signage • Electrostatically dissipative floor covering (floor had to be renewed anyway, otherwise this measure would not have been taken) • No spark generating 'hot work' such as welding (for such work, tank has to be emptied and bus must be electrically isolated) • Grounding points for the buses • 2 mobile gantries for working on the bus roof (Figure 3-7) • Insulated pole to rescue a person incapacitated from electric shock

Area of Activity	Details
	• Risk management plan and emergency response plan developed/amended and implemented • Training measures, see below
Alarm system	• 9 hydrogen sensors under the roof
Alarms	• 10% LEL: Beacons and sound alarms activated; Ventilation system increases air supply and roof dome sections open (see below); electrical shutdown except for ATEX lighting; building to be evacuated • 20% LEL: Doors opening, ventilation system keeps working
Venting system	• Ventilation/heating systems (non-ATEX) switches from balanced 'inlet and exhaust air' mode to 'inlet air only' mode in case of alarm, doubling the amount of inlet supply and creating slight overpressure • 9 spring-loaded roof dome sections (Figure 3-6) • Manual activation possible but no manual de-activation • One hydrogen vent line in the building with quick connect coupling, to empty/depressurise the piping and/or hydrogen tank(s) onboard a bus and transfer the hydrogen outside through the ceiling
Training	• Training for the technicians doing maintenance/repair of the hydrogen and/or high-voltage system, following the guidelines of the German Statutory Accident Insurance[1] Hydrogen awareness training for all depot staff, particularly those working in the maintenance area
Personal protective equipment	• Antistatic clothing/shoes • Hand-held 'hydrogen sniffers' to check items such as piping on board the buses
Quarantine / venting place outside the building	• Special open-air area for bus to be parked in case of a suspected hydrogen leak or damage to the hydrogen system or an unsafe battery state • 10 m safety clearance around the bus within which no flammable substances to be stored and no sources of ignition within or above (Figure 3-8), no other vehicle allowed to enter this area when quarantine place is occupied • Pole with hydrogen vent line (not included in Figure 3-8)

[1] 'Training for Work on Vehicles with High Voltage Systems' and 'Gasantriebssysteme in Fahrzeugen - Qualifizierung für Arbeiten an Fahrzeugen mit Gasantrieb', see Annex B.

Area of Activity	Details
Approximate costs	About €250,000, including the electrostatically dissipative floor covering
Current additional steps (2024)	• Mobile gantries to be replaced by a stationary structure for working on the bus roofs (€280,000). • Other non-specialised FCB maintenance bays to be equipped with hydrogen sensors to facilitate carrying out work on non gas-carrying components on FCBs; sensors will trigger alarm and switch-off any power supply; not all details decided yet.

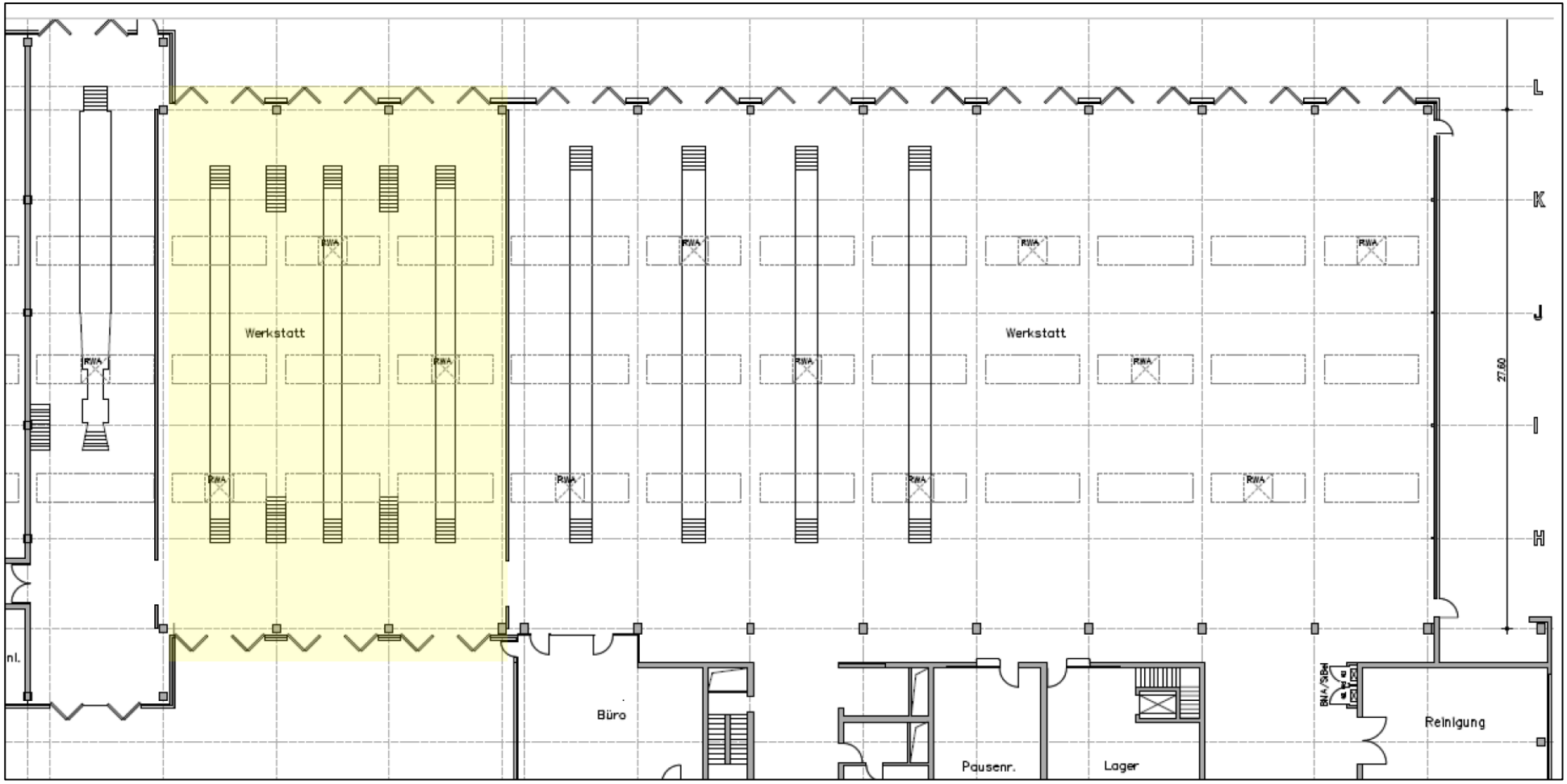

Figure 3-5: Modified Maintenance Workshop in Wuppertal / 1.
Floorspace in light yellow shading showing current area equipped for FCB maintenance. Other bays to the right to be adapted in the near future (see Table 3-2 'Current Additional Steps'). Drawing by permission of WSW mobil.

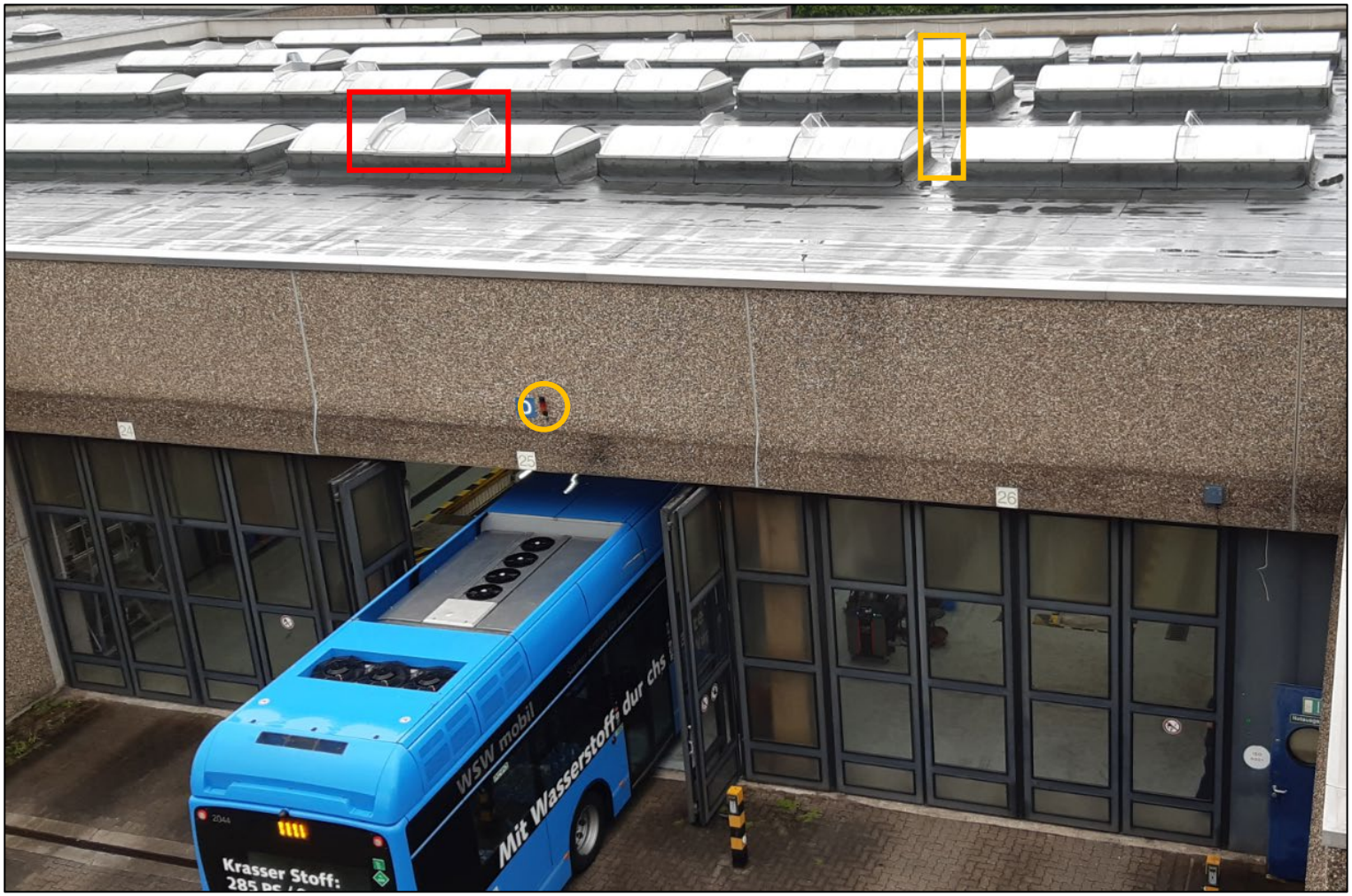

Figure 3-6: Modified Maintenance Workshop in Wuppertal / 2.
External view of facility showing FCB entering the workshop , green-yellow-red signal light (orange circle), outside section of the vent line to empty the hydrogen bus tank (orange rectangle) and spring-loaded roof dome sections that open in case of alarm (one indicated by red rectangle). Photo by permission of WSW mobil.

Figure 3-7: Modified Maintenance Workshop in Wuppertal / 3.
Internal view of workshop showing FCB in maintenance bay with mobile gantry at its rear, beacons and sound alarm devices (orange circle) and inside section of the vent line (rigid part in orange rectangle). Photo by permission of WSW mobil.

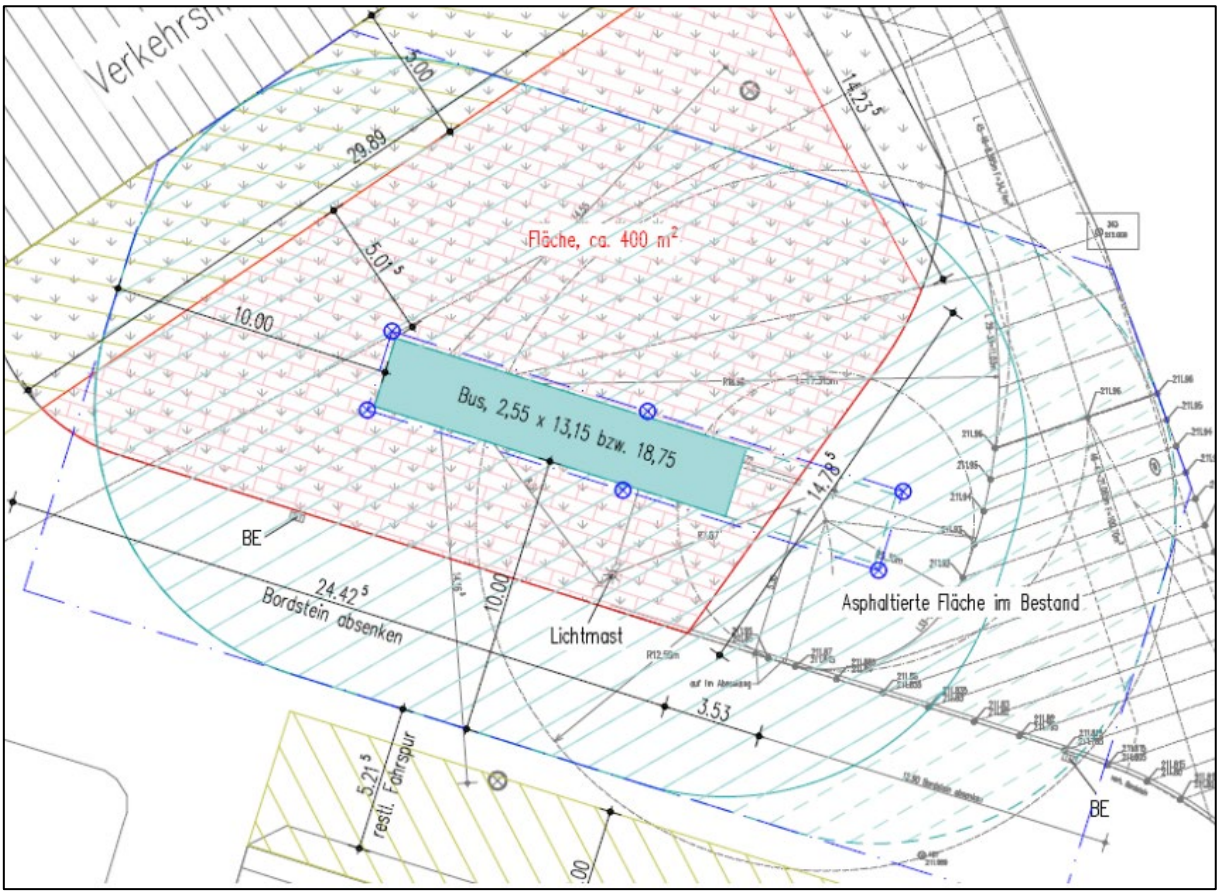

Figure 3-8: Open Air Safe Parking Area in Wuppertal Depot.
10 m safety clearance around the vehicle, edged and striped in dark green (some 790 m^2). When the safe parking place is in use, no other vehicles is allowed to traverse this area. Drawing by permission of WSW mobil.

Annex A Objectives of the JIVE / JIVE 2 projects

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

The objectives of both projects can be summarised as follows:

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

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

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

Annex B References and Useful Resources

Resources	Where to find the Resources
FCB Projects	• Website on FCB projects with a knowledge base and information present and past projects: https://www.fuelcellbuses.eu/ • JIVE / JIVE 2 Best Practice Report and other documents from these projects: https://www.fuelcellbuses.eu/publications/ • 'Einführung von Wasserstoffbussen im ÖPNV' ('Introduction of hydrogen buses in public transport'), Bundesministerium für Verkehr und digitale Infrastruktur, 2018; https://www.now-gmbh.de/aktuelles/pressemitteilungen/neue-publikation-der-now-gmbh-leitfaden-fuer-busse-mit-alternativen-antrieben/ • 'Requirements for depots and workshops when using citybuses with clean and/or zero emission drivesystems', VDV recommendation 825, 2023 / 'Anforderungen an Betriebshöfe und Werkstätten beim Einsatz von Linienbussen mit sauberen und/oder emissionsfreien Antrieben'. VDV-Schrift 825, 2023; https://knowhow.vdv.de/documents/825/ (read-only for non-members; click on 'Volltext (E)' for English version)
Hydrogen Characteristics, Risks and Best Practice; see also Annex C	• http://www.h2data.de/ • 'General Hydrogen Safety Facts'; https://www.fuelcellbuses.eu/wiki/safety-framework/general-hydrogen-safety-facts • 'Initial Guidance for Using Hydrogen in Confined Spaces - Results from InsHyde; HySafe Deliverable D113, 2009; https://www.hysafe.org/download/1710/HYSAFE_D113_version_1.1.pdf • 'Understand LEL and UEL for Flammable Gases: Values, Hazards, Measurement, and Risk Mitigation' https://blog.projectmaterials.com/category/epc-projects/project-site-safety/lel-uel-flammable-gas/ • H2Tools Portal, for example: https://h2tools.org/bestpractices/best-practices-overview and https://h2tools.org/sites/default/files/HydrogenSafetyChecklist.pdf • Reference Documents of the European Hydrogen Safety Panel https://www.clean-hydrogen.europa.eu/get-involved/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 ➢ For questions and specific requests, JRC Hydrogen Safety address: JRC-PTT-H2SAFETY@ec.europa.eu
Explosion Protection	**EU Directives setting the framework and minimum standards for national legislation** • Directive 2014/34/EU 'Equipment and protective systems intended for use in potentially explosive atmospheres', also referred to as 'ATEX Equipment Directive' or 'ATEX 114' (since it is based on Article 114 of the Treaty on the Functioning of the European Union https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:31999L0092, available in various languages • An overview of the national implementations of Directive 2014/34/EU can be found here: https://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:32014L0034 • Directive 1999/92/EC 'Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres', also referred to as 'ATEX Workplace Directive', or 'ATEX 153' https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:32014L0034, available in various languages • A guide to good practice for implementing Directive 1999/92/EC in various languages can be found here: https://op.europa.eu/en/publication-detail/-/publication/c23f5429-1632-4b61-9eb1-a6c0e60828e0
Maintenance Workshops for and Maintenance Work on FCBs	• Wasserstoffsicherheit in Werkstätten' ('Hydrogen Safety in Maintenance Workshops') German Statutory Accident Insurance (DGUV / Deutsche Gesetzliche Unfallversicherung e.V.); DGUV Information 209-072, 2021; https://publikationen.dguv.de/regelwerk/dguv-informationen/265/wasserstoffsicherheit-in-werkstaetten • 'Training for Work on Vehicles with High Voltage Systems', DGUV Information 209-093, 2023; https://publikationen.dguv.de/regelwerk/dguv-informationen/4727/training-for-work-on-vehicles-with-high-voltage-systems • 'Gasantriebsysteme in Fahrzeugen - Qualifizierung für Arbeiten an Fahrzeugen mit Gasantrieb' ('Training for Work on Gas-Powered Vehicles'), DGUV Fachbereich Holz und Metall Aktuell, FBHM-099, 2018; https://publikationen.dguv.de/regelwerk/publikationen-nach-fachbereich/holz-und-metall/fahrzeugbau-antriebssysteme-instandhaltung/3528/fbhm-099-gasantriebsysteme-in-fahrzeugen-qualifizierung-fuer-arbeiten-an-fahrzeugen-mit-gasantrieb • 'Safety Considerations for Maintenance Facilities', Ballard Power Systems, 2016; https://www.fuelcell-buses.eu/sites/default/files/documents/Safety%20Considerations%20for%20Maintenance%20Facility_0.pdf • 'Adapting Bus Depot Facilities for the Maintenance of Hydrogen Fuel Cell Electric Buses'; Ballard Power Systems, 2020; https://info.ballard.com/adapting-maintenance-facilities-for-hydrogen

	• 'Depot Adaptations for Clean Bus Technologies', UITP Factsheet, Clean Bus Series 2, 2023; https://cms.uitp.org/wp/wp-content/uploads/2024/07/6_UITP_Bus_Hydrogen_Depot_Factsheet_Nov_2023.pdf
Fire Protection in Depots	• 'Ontwerprichtlijnen brandveiligheid voor stallingen zeroemissiebussen', CROW-KpVV, 2022 https://www.crow.nl/kennis/bibliotheek-verkeer-en-vervoer/kennisdocumenten/ontwerprichtlijnen-brandveiligheid-ze-stallingen • 'Brandschutz in Betriebshöfen für Linienbusse', VdS 0825: 2023-03 (01), VdS Schadenverhütung GmbH, 2023; https://shop.vds.de/publikation/vds-0825
Consultations with Stakeholders	• JIVE / JIVE 2 Best Practice Report, section 1.3; https://fuelcellbuses.eu/public-transport-hydrogen/final-best-practice-report-d326-d329 Experiences from the CHIC project are summarised in a set of documents: • 'Influencing factors to the acceptance of fuel cell and hydrogen technologies in public transport', 2013 (focussing on bus drivers, stakeholders and the general public) • 'Extract from influencing factors to the acceptance process of FCH technologies' (extract from the above report with key learnings), 2014 • 'Issues of concern to external stakeholders and critics and pathways to their resolution: Reflections on change after 2 years', 2015 available at https://fuelcellbuses.eu/projects/chic
Costs	'Analysis of investments in workshops for fuel cell buses and hydrogen refuelling stations', Lozanovski, A and Ko, N, 2015; Deliverable 3.11 from the CHIC project, 2010 – 2016, https://www.fuelcellbuses.eu/public-transport-hydrogen/analysis-investments-workshops-fuel-cell-buses-and-hydrogen-refuelling
Staff Training	The European Hydrogen Observatory operates a searchable database for training programmes. The type of training, a focus on hydrogen in transport and languages can be selected. Search results come as a list and also map-based: https://observatory.clean-hydrogen.europa.eu/learn-about-hydrogen/training-programmes Courses in this field range from online units to hands-on training. A careful search is recommended. Indicative samples of what can be expected include:

	• https://www.kiwa.com/en/service2/training/hydrogen-vehicles-technician/ • https://www.tuvsud.com/en-us/store/academy-us/transportation-industry/safety/36-34-22-1001 • https://www.siccogen.com/categorie-produit/formation-hydrogene

Annex C FCB Propulsion Technology and Related Risks

The basic technological concept of FCBs is relatively simple.

- Hydrogen and oxygen are fed into an on-board fuel cell which generates electricity,
  - The hydrogen is provided from on-board storage in tanks,
  - The oxygen comes in the air drawn in from outside the vehicle and pumped into the fuel cell.
- The electricity is used to
  - Drive one or more electric motors to propel the vehicle,
  - Charge batteries, which can also store energy from regenerative braking.

The electric motors can be driven by power from the batteries, the fuel cells or some combination, depending on the design of the drivetrain. The application of this concept varies in vehicles provided by different vehicle manufacturers, but the fundamental basics are the same[2].

C.1 Hydrogen

There are inherent risks in handling hydrogen, as with any flammable gas or liquid, including gasoline and other fossil fuels. However, when used in accordance with appropriate guidelines, hydrogen fuel has been proven to be safe for public transportation, just as with traditional fuels.

There are currently thousands of hydrogen-fuelled buses, trucks and cars operating around the world, and they have travelled many millions of kilometres in varied environments, safely transporting thousands of passengers and goods daily. As with any vehicle, proper maintenance has been essential in ensuring safe and efficient operations.

As has been outlined in section 2.1, it is important to take account of the properties of hydrogen when introducing it into a bus fleet. Its characteristics include: [3]

- About 14 times lighter than air and rises and disperses quickly in air,
- Colourless, odourless, tasteless; invisible to the human eye in sunlight,

[2] Based on 'Introduction of hydrogen buses in public transport', see Annex B.

[3] Based on 'Safety Considerations for Maintenance Facilities', 'Adapting Bus Depot Facilities for the Maintenance of Hydrogen Fuel Cell Electric Buses' and http://www.h2data.de/ (see Annex B).

- Non-corrosive, non-toxic, non-carcinogenic and not a significant environmental risk to water,
- Not flammable/explosive unless oxidising substances, such as oxygen or air, are present
- Not subject to auto-ignition under ambient conditions, or to decomposing
- Low ignition energy
- Large flammability/explosive range, meaning it can be ignited in a very wide range of concentrations,
- Burns rapidly with an invisible flame in daylight, and with very little heat radiated from the flame, so difficult to detect

Table C-1 presents safety properties of hydrogen compared with some other fuels. They show that the main characteristics of hydrogen and methane, the main component of natural gas, are not significantly different. The lower flammable limit in air, autoignition temperature and flame temperature of both gases are in the same range.

While the minimum ignition energy of hydrogen is an order of magnitude less than that of methane and gasoline vapour, in practice however, most potential ignition sources, such as a static discharge, exceed this minimum energy. This means that these sources would ignite mixtures of air with any of the three substances. Similarly, the autoignition temperatures of all three substances mean that hot surfaces are ignition risks.

However, hydrogen is much lighter than natural gas and has a wider flammability range.

Along with the fact that hydrogen molecules are much smaller than those of methane, the key implication on the use of hydrogen is that leak tightness is very important, and measures to ensure and monitor leak tightness require more effort.

Guidelines for working safely with hydrogen are well established. Selected items can be found in Annex B.

Table C-1: Safety-related Properties Hydrogen and Other Fuels.
Based on 'Wasserstoffsicherheit in Werkstätten' (Hydrogen Safety in Maintenance Workshops), and 'Safety Considerations for Maintenance Facilities', see Annex B. Consider these numbers as indicative reference, primarily for comparison between the listed fuels. Numbers in literature vary to some extent. That is partly due to the determination procedure and exact reference conditions applied. Reference conditions can be, for example, 0°C and 1 bar absolute or 20°C and 1.013 bar absolute. 1 bar is roughly the air pressure at sea level. The autoignition energy in air varies across the flammability range; numbers in the table are the minimum values. Some of the properties also depend on air moisture. In day-to-day practice, these variations do not play a key role.

	Hydrogen	Methane	Gasoline	Diesel
Buoyancy: Gas or vapour density relative to air	0.07	0.55	2 to 4	4 to 5
LFL / LEL (gas/vapour in air, by volume)	4%	5%	0.6%	0.6%
UFL / UEL (gas/vapour in air, by volume)	77%	15%	8%	6.5%
Minimum ignition energy in air (mixtures within the flammable range; numbers quoted represent the lowest values, i.e. under 'best' conditions to ignite)	0.02 mJ	0.28 mJ	0.24 mJ	Not available
Autoignition temperature	560°C	595°C	220°C	250°C
Flame temperature in air	2045°C	1918°C	2197°C	Not available
Boiling point at about 1 bar absolute	-252°C	-162°C	30 to 215°C	170 to 390°C

C.2 High Voltage Electricity and Hydrogen – Electricity Interaction

The major risks arising from the presence and maintenance of high voltage electricity devices relate to:

- Maintenance personnel from suffering electrical shock, and
- Electrical ignition sources, such as sparks could result in explosion in the presence of ignitable mixtures of hydrogen and air.

Guidelines and training for working safely with electrical installations on buses are even more common than those for hydrogen, due to e.g. the long experience with diesel-hybrid (electric) buses. Most, if not all, jurisdictions, will have explicit regulations covering electrical installations, and work processes. It is essential that these regulatory requirements are understood and followed.

There are companies working on internal combustion engines for hydrogen. Buses with these engines would likely not include high-voltage equipment like that found on FCBs.

C.3 High Pressure

The energy in 1 kilogram of hydrogen gas is about the same as the energy in 2.8 kilograms of gasoline, or about 3.8 litres of gasoline. However, hydrogen has a low volumetric energy density when compared with some other energy storage materials, such as hydrocarbons like gasoline. This means that it takes up a relatively large volume for a given amount of energy stored. It is therefore commonly stored onboard a vehicle as a compressed gas to achieve the required operational driving range. The typical storage pressure on buses is 350 bar, but there are vehicles, most commonly cars, with 700 bar. On-board storage of liquefied hydrogen at below -252°C is another option, though not currently implemented by any bus manufacturer and therefore not addressed here.

The main risks that need to be managed with high pressure hydrogen equipment are similar to those that need to be taken into account with any high-pressure equipment used for gases such as nitrogen, air, or natural gas.

However, there may be additional risks and management processes documented by the bus manufacturer. It is imperative that these, as with all other safety requirements, are understood and followed.

If there is no vent line to defuel a bus in a maintenance bay, perhaps the most critical, and immediate safety procedure is to move the bus outside the maintenance facility, in the event of an actual or suspected hydrogen leak, or damage to any vessel or pipework containing hydrogen. The bus must be parked in a safe place where there are no ignition sources within a safe radius, and monitored. The bus tanks may need to be depressurised in a controlled way.

C.4 Working on Vehicle Roof

Depending on the bus manufacturer, FCBs can often have components, such as hydrogen vessels or batteries, located on the roof. If so, appropriate equipment for safe working at height needs to be in place.

- Mobile gantries or platforms to enable staff to work safely on the bus roof (see Figure 3-7);
- Alternatively, stationary structures to enable staff to work safely on the bus roof (see Figure C-1).

C.5 High Power Density Batteries

High power-density batteries are an additional safety concern, quite separate from the hydrogen related risks. Fire protection management procedures in depots housing buses such as FCBs and BEBs need to take this into account. Annex B lists two resources for this issue.

Figure C-1: Maintenance bay in newly built workshop with stationary platform for working on vehicle roof.
Top and bottom picture taken from almost opposite angles of the same maintenance bay. Movable elements (indicated by red arrows) can close any gap between platform and bus once the bus is in position. Workshop of moBiel/Germany. Photos by permission of PLANET and moBiel.

Project coordination:

ERM

Project dissemination:

Hydrogen Europe

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Clean Hydrogen Partnership

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