SPECIFICATION

Contract Title	**Hydrogen Bus Operator**
Contract Reference	**P0420**

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1. Definitions

CAHB	Means the 'Clean Air Hydrogen Bus Pilot'
TEP	Means 'Tyseley Energy Park'
ULEV	Means 'Ultra Low Emissions Vehicle'
NO2	Means 'Nitrogen Dioxide'
TfL	Means 'Transport for London'
TfWM	Means 'Transport for West Midlands'

2. Summary/Overview

2.1. The Council is responsible for ambient air quality and cleaner air under the Air Standard Regulations. With road traffic as a primary source of harmful emissions in the city, heavy diesel vehicles, including buses, are key contributors to nitrogen dioxide (NO2) emissions. By enabling the development of ultra-low and zero emission re-fuelling infrastructure using alternative low and zero emission fuels such as hydrogen, the Council is providing leadership in enabling public and private sector fleets to transition to low and zero emission vehicles and realising the ambitions of Birmingham Connected Transport Strategy to deliver Green Travel Districts, health and well-being.

2.2. In February 2015, the Council's commissioned 'Birmingham Blueprint' study which identified the type of low and zero emission fuel technologies required by different fleets operated within public and private sector business. The study provided the baseline for the type of low and zero emission fuel technologies and re-fuelling infrastructure that would be required to reduce harmful emissions. This considered both electric recharging and hydrogen fuel and concluded that the 7-hour recharging for electric buses was impractical due to the number of buses and depot facilities. Hydrogen fuel dispenses in 5 to 10 minutes. The next steps required Research and Development studies to understand the renewable energy systems and scale of what was required; testing commercial viability of hydrogen buses and hydrogen as a zero emission fuel technology.

2.3. The Government issued the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations in July 2017 which identified Birmingham as one of the areas experiencing the greatest problem with NOS exceedances. The Plan requires the Council to undertake assessments aimed to deliver the best option to achieve statutory NO2 limit values within the shortest possible time. The plan for tackling NO2 exceedances will need to be finalised by Summer 2018. The plan also requires local authorities to consider innovative options and new technologies to reduce emissions including; public and private uptake of ultra-low emission vehicles (ULEVs) and using innovative retrofitting technologies and new fuels.

3. Scope

3.1. The Council has collaborated with TfL and Aberdeen City Council to enable a deployment of 100 hydrogen buses by 2020. Whilst this ensures achieving economies of scale and reduced costs for each city, there are no joint risks with this project, in that through collaboration, with TFL and Aberdeen, their performance does not impact on the Council or project funding.

3.2. Initially Birmingham will have 22 buses (including 2 spare buses due to piloting refuelling), on the basis that 20 buses is the optimal number for running a bus route and the grant funding requires this number to ensure impact on emission reduction on the bus route.

3.3. To ensure that this development is not just a pilot scheme, work will continue to develop towards establishing a city wide re-fuelling infrastructure with a commercially viable price for hydrogen and vehicles. Plans for deploying future hydrogen re-fuelling infrastructure, bus and other hydrogen vehicle models are being aligned with UK and EU funding sources and with other cities. This will ensure that the economies of scale being developed will drive down costs making hydrogen vehicles and fuel the zero emission choice of the future. The Hydrogen Bus Operator will be a key partner in delivering these aims.

3.4. The Hydrogen Bus Operator will be involved in the final specification of the Hydrogen Buses, advising on; the fit-out requirements, servicing and maintenance requirements, and any other relevant requirements required.

3.5. This project will involve collaboration between the Council, Bus Operator, Bus Manufacturer and Hydrogen Producer (based at Tyseley Energy Park). This will require the Bus Operator to enter into separate agreements with the Bus Manufacturer for Servicing & Maintenance, and the Hydrogen Producer for Refuelling.

3.6. Due to the requirement for collaboration there will be variables, such as Servicing & Maintenance and Refuelling costs, which can only be estimated at this time. These costs will be agreed between the Bus Operator, the Bus Manufacturer and the Hydrogen Producer once a Bus Operator has been appointed.

3.7. Suppliers are asked to submit an indicative bid for the work outline in this specification which will form the basis of the evaluation to appoint a Bus Operator.

3.8. Tenderers will be required to ascertain, at their own cost, the information necessary to make a compliant and accurate bid. The successful supplier will enter into a contract to work with the Council as a development partner on this project. However, the lease agreement with the Council for the Hydrogen Buses will not be entered into until agreements between the Bus Operator, Bus Manufacturer and Hydrogen Producer have been finalised. This work will take place between January 2018 and March 2018 with support from the Council.

3.8.1. If, following these discussions the Bus Operator is no longer able to honour the bid submitted, for example due to higher than estimated hydrogen costs, the lease agreement will not be entered into and the Bus Operator service will either be retendered or abandoned.

3.9. Routes

3.10. The following roads have been identified as candidates for the Hydrogen Bus Route;

3.10.1. Of priority - A4540 Dartmouth Middleway on the east side of the inner ring road

3.10.2. Of priority - Digbeth – including Moor St Station, Selfridges, Digbeth Coach/Bus station areas.

3.10.3. Of priority - A38/A4400 Queensway

3.10.4. Of priority - Routes relating to above that also include A5127 Lichfield Road, close to the M6

3.11. These roads have been identified due to the presence of high emissions.

3.12. The Bus Operator must have in place an existing licence to operate bus routes on at least one of the roads listed in 3.10.1.

3.12.1. It is expected that the Hydrogen Buses will be used to replace an existing like for like diesel route.

3.13. The proposed route will need to meet the following criteria to qualify for this project;

3.13.1. A minimum of 20 buses required to run the route.

3.13.2. Each bus should be operational for 15 hours on the route.

3.13.3. Each bus should travel 65,000 km per annum (funding requirement)

3.14. If a supplier has more than one route which meets the criteria of this project the decision for which route to select will be based on targeted determination (i.e. the route that has the highest emissions).

3.15. Refuelling

3.16. The CAHB pilot is set to test the potential of developing a hydrogen market. This will be delivered through producing hydrogen at Tyseley Energy Park (TEP), a private sector development covering a 1 acre site in the Tyseley Environmental District. TEP received full planning permission in November 2016 for a low/zero emission re-fuelling hub for commercial and public sector vehicles from buses and bin wagons to vans and taxis.

3.17. ITM Power, as a private sector hydrogen provider, have worked alongside TEP and the Council in the design and delivery of hydrogen infrastructure appropriate for re-fuelling buses to meet the same operational requirements as for diesel buses.

3.18. The hydrogen infrastructure will be developed over the first year from January 2018 ahead of the buses being delivered in March 2019. The hydrogen plant will be tested in 1 mega-watt ‘stack’ developments up to 3 mega-watts, which is the requirement for 22 buses. This will ensure everything works before the buses are delivered and operationally tested.

3.19. To ensure economies of scale the Hydrogen Buses will be required to refuel at the Tyseley Energy Park.

3.20. Current estimates place the price of hydrogen from Tyseley Energy Park at £6.75 per kilogram, below the current market rate of £10 per kg. This price is subject to negotiation which the Council will expect the Bus Operator to be involved in.

3.21. Further economies of scale are expected to reduce this price, however no guarantees are provided by the Council and the Bus Operator is expected to take on all liability for changes in refuelling costs.

3.22. The appointed Bus Operator will be expected to agree a hydrogen price with ITM (the Hydrogen Provider) which will be reviewed over an agreed period and will be subject to benchmarking costs towards commercial viability. The Council will support this discussion which will take place from January to March 2018.

3.23. Servicing & Maintenance

3.24. The options available under the Call-off exercise for the delivery of Servicing & Maintenance are;

3.24.1. Option 1 – Manufacturer provided servicing & maintenance provided by on-site engineers covering all requirements.

3.24.2. Option 2 – Manufacturer provided servicing & maintenance for the drive line (e.g. hydrogen tanks, fuel cell, tractor motors, hybrid integration) only. The standard 'nut's & bolts' servicing & maintenance requirements will be left to the Bus Operator.

3.24.3. Option 3 – Part Package approach allowing for monthly payments covering the hydrogen elements on a 'use it or lose it' basis. Parts will be replaced when required at no additional cost.

3.25. The actual service & maintenance agreement will be made between the Bus Operator and Bus Manufacturer, and the details of this will be finalised during the Call-off process to appoint the Bus Manufacturer. This process will be led by TfL and supported by the Council and Bus Operator.

3.26. The following warranties are expected to be in place for the Hydrogen Buses;

3.26.1. Bus (bumper to bumper) 2-3 years

3.26.2. Drivetrain (fuel cell, hybrid drive line and motors etc.) 3-5 years

3.26.3. Body 3 years

3.26.4. Chassis 12 years

3.27. The above warranties are indicative and provided for information only. The length of each warranty may form part of the Bus Manufacturer Call-off process and as such be subject to negotiation. The Bus Operator may therefore have the ability to influence the level of warranty.

3.28. Tenderers are asked to include as part of their bid their preferred Servicing & Maintenance option and the budget (per bus, per year) they have available for servicing and maintenance.

3.29. The Bus Operator is required to have a Birmingham based depot using a local workforce of drivers and technical support staff that are open to being trained in operating the re-fuelling, servicing and maintenance of Hydrogen Buses.

3.30. As part of the Service & Maintenance arrangements the Bus Operator must make provision for a minimum of 5 apprenticeships. This may be provided in house or arranged as part of the Service & Maintenance agreement with the Bus Manufacturer.

3.30.1. If required the Council will be able to support the apprenticeship programme.

4. Supplier Responsibilities

4.1. The Bus Operator shall be responsible for;

4.1.1. Providing expert advice during the procurement of the Hydrogen Buses

4.1.2. Operating a commercial Hydrogen Bus Route on one of the roads identified.

4.1.3. All associated costs for operating the Hydrogen Buses, including but not limited to;

4.1.3.1. Refuelling

4.1.3.2. Servicing & Maintenance

4.1.3.3. Staffing

4.1.3.4. Additional Fit-out of the Hydrogen Buses

4.1.3.5. Insurance

4.1.4. Monitoring and reporting of bus operation and refuelling in line with the FCH JU and OLEV funding requirements (see Appendix 1 for detail). This may require telematics to be installed in the Buses to collect journey data.

4.2. The Bus Operator will be liable for ensuring the Hydrogen Buses are properly maintained and kept in working order. Any damage, accidental or otherwise, will be the responsibility of the Bus Operator to rectify.

4.3. The Bus Operator will be required to enter into separate agreements with the Hydrogen Provider for the refuelling costs, and with the Bus Manufacturer for the Serving & Maintenance costs.

4.4. The Bus Operator will be responsible for ensuring an implementation plan is in place so that services begin without delay following the delivery of the Hydrogen Buses.

4.5. The Bus Operator will be responsible for specifying and paying for the additional fit-out work required for the Hydrogen Buses.

4.5.1. The Bus Operator is required to provide estimated costs and a budget as part of their Bid.

4.6. The Bus Operator shall ensure processes are in place to maximise the usage of the Hydrogen Buses.

4.6.1. They are on a commercially viable route as agreed with the Council (see paragraph 3.9).

4.7. As a minimum the Hydrogen Buses must meet the operational requirements for the FCH JU funding, i.e. 65,000 km travelled per annum per bus.

4.7.1. Breakdowns and repairs will be managed in a time critical manner.

4.7.2. Where a Hydrogen Bus is expected to be off the road for an extended period of time, the Bus Operator will make the Council aware and will have in place a plan to return the Hydrogen Bus to service as soon as possible.

4.8. The Bus Operator will provide a named Account Manager for this contract.

4.9. The Bus Operator will provide a named Technical Advisor who will work with the Council on the fit-out specification work, and any other work related to the selection of the Bus Manufacturer.

4.9.1. The Bus Operator should expect to invest a suitable amount of time in the Bus Manufacturer process which is expected to take at least 3 months from initial scoping work to appointment.

5. Technical and Quality Requirements

5.1. The Bus Operator will be required to produce a Servicing Plan for each Hydrogen Bus which will detail the level and frequency of servicing.

5.2. The Bus Operator will use only parts approved by the Bus Manufacturer for serving and repair work.

5.3. The Bus Operator will be responsible for ensuring all staff are appropriately trained to operate, maintain and service the Hydrogen Buses.

5.4. The Bus Operator will be required to produce a contingency plan to ensure service operation continues under unforeseen circumstances e.g. interruption to the hydrogen fuel supply.

6. The Councils Responsibilities

6.1. The Council shall work with the Bus Operator to produce a final specification for the Hydrogen Buses.

6.2. The Council shall ensure the timely placement of the Hydrogen Bus order to ensure delivery of the Hydrogen Buses by March 2019.

6.3. The Council shall work with the Hydrogen Provider to be located at Tyseley Energy Park to support the bus operator to ensure provision of hydrogen for the refuelling of the Hydrogen Buses.

6.4. The Council shall work with the Bus Operator to identify the most appropriate bus route for the Hydrogen Buses.

7. Data

7.1. The Service Provider shall provide the Council with any requested data relating to the service within 7 days of the date of the Council's request. The Council will treat the data as "confidential information" where possible and will comply with its obligations under the Data Protection Act 1998.

7.2. Financial data will be treated as 'commercially sensitive' and will be managed in line with Council policy and all applicable regulations.

8. End User Experience

8.1. The fit-out of the Hydrogen Buses will be designed to ensure;

8.1.1. Passenger safety
8.1.2. Accessibility
8.1.3. Comfort
8.1.4. Adequate capacity

8.2. All related legislation must be adhered to when finalising the internal fit-out of the Hydrogen Bus.

8.3. The Bus Operator will be responsible for providing a regularly scheduled bus service on the identified route in line with Transport for West Midlands bus operator licence arrangements.

8.3.1. The Bus Operator will ensure the service is delivered in-line with industry best practice and the service agreement with TfWM.

9. Marketing & Promotion

9.1. The Service Provider shall carry out sufficient marketing and promotional activities, in conjunction with the Council and other partners, to promote the Hydrogen Bus project.

10. Lease Contribution

10.1. The Bus Operator will be required to contribute to the purchase of the Hydrogen Buses.

10.2. The below table shows the funding model for the Hydrogen Buses;

Funding Source	**Contribution Per Bus**	**Total Contribution (x22 Buses)**
OLEV Low Emission Bus Funding	£67,000	£1,474,000
Horizon 2020 / Fuel Cell and Hydrogen Joint Undertaking (FCH JU)	£185,490	£4,080,800
Bus Operator minimum lease cost contribution	£149,510	£3,289,200
GBSLEP Local Growth Fund (LGF)	£98,000	£2,156,000
Total	**£500,000**	**£11,000,000**

10.3. The Bus Operator will be required to provide confirmation of their contribution as part of their Bid.

10.4. It is expect that the Bus Operator will provide funding equal to the cost of a new Euro 6 diesel bus.

10.5. The total cost per bus provided in the table above is an estimate based on market engagement and may be subject to change.

10.6. The final cost of the Hydrogen Buses will be established through the Bus Manufacturer Call-off process.

10.7. This pricing covers the cost of a ‘base specification’ for the buses and does not include the additional ‘fit-out’ cost.

10.8. Payment of the Lease Contribution will be made to the Council in phases;

10.8.1. 20% at order placement
10.8.2. 30% mid-way through production
10.8.3. 50% on delivery

10.9. The payment schedule above shows the Councils preferred position however this may be subject to change depending on the outcome of the Bus Manufacturer Call-off process.

11. Customer Services and Support

11.1. A customer care line should be available during core hours of;

11.1.1. Weekdays – 8am-8pm
11.1.2. Weekends – 8am-6pm

12. Management Information and Reporting

12.1. The Bus Operator will be required to produce FCH JU and OLEV reports outlined in Appendix 1. This is provided as an indication of the level of reporting that is required.

12.2. The Council may make reasonable requests for additional reports from time to time.

13. Service Levels & Performance Monitoring

13.1. The Council and the Bus Operator shall, meet on a regular basis to discuss the Bus Operators performance in relation to the following items:-

13.1.1. Service operation
13.1.2. Up-time of the Hydrogen Buses
13.1.3. Apprenticeships

13.2. Any other factors affecting the Service Provider's performance.

13.3. The Bus Operator will be required to produce the FCH JU and OLEV reports outlined in Appendix 1.

14. Expiry or on Termination of Contract

14.1. On termination of the contract the Bus Operator shall provide the Council with a demobilisation plan/exit strategy.

14.2. The Bus Operator will have the option to purchase the Hydrogen Buses at the end of the contract for a nominal fee based on the residual value of the Buses.

15. Contract Terms

15.1. Following award there will be an initial Mobilisation Phase of three (3) months due to the requirement for the Bus Operator to reach separate agreements with Hydrogen Provider and the Bus Manufacturer.

15.2. Following the successful completion of the Mobilisation Phase the Bus Operator will enter into a lease agreement to provide the services laid out in this Specification.

15.2.1. The period of the lease agreement will be seven (7) years from the date of delivery of the Hydrogen Buses.

15.3. Assignment of all or any part of the contract will require written approval by both parties.

15.4. The Council reserves the right to terminate this contract without penalty in the event of a change of control of the Bus Operator, or in the event of a Novation request.

15.5. A draft copy of the proposed contract & lease agreement is included in the Tender Documents.

15.6. The provided Terms and Conditions represent the Councils preferred position.

15.6.1. Tenderers may request changes/revisions to be made to the Terms and Conditions so long as they do not materially change the nature of the procurement.

15.6.2. Requests must be made as part of the Tender Submission, and should include the original clause and the proposed replacement clause.

15.6.3. The Council will have final say on any proposed amendments.

15.6.4. Where the Council is unable to enter into a contract with the first ranked supplier due to contractual differences, the second ranked supplier will be approached and so on.

15.7. For the avoidance of doubt, the Council will only be providing the initial funding for the purchase of the Hydrogen Buses outline in paragraph 10.2. The Bus Operator will be responsible for all other costs in required to operate the Hydrogen Buses for the length of the contract.

16. Minimum Requirements

16.1. For the purposes of this procurement the following will be treated as minimum requirements;

16.1.1. A compliant bus route

16.1.2. The minimum contribution

16.1.3. The use of Tyseley Energy Park

16.1.4. A Birmingham based depot

17. Appendix 1 – JIVE Reports

Table 1.1 Key Performance Indicators and performance targets for the fuel cell buses.

KPI no.	Parameter	FCH JU 2016 AWP target	JIVE targets (KPIs)
FCB-1	Vehicle operational lifetime	>20,000 hours initially, with minimum 25,000 hours as project target3	Tender specifications and project require a bus operation of over 8 years.
FCB-2	Distance travelled	Minimum 100,000 km per bus in 3 years	Minimum distance travelled will be 44,000km/year, average of 59,000km and a maximum of 90,000km (in Slagelse).
FCB-3	Operating hours per fuel cell system	Number of hours according to manufacturer's warranty	15,000 hours or 5 years, whichever is lower (at the project start), >20,000 hours by project end – stack replacements built into maintenance costs.
FCB-4	Availability of bus	>90% on a fleet basis after an initial 6 month ramp-up phase.	Tender specifications and contracts require >90% vehicle reliability, but allow for a 6 month teething phase where lower reliability is expected (based on CHIC learning).
FCB-5	Mean distance between failures *MDBF*	Fuel cell MDBF >2,500 km.	An MDBF of >2,500 km (after the teething period) will be a specification in the procurement exercises and will be stipulated in the contracts.
FCB-6	Specific fuel consumption	< 9 kg / 100 km (solo bus, 12–13.5 m), < 14 kg / 100 km (articulated bus, 18 m).	These figures are will be included as a minimum efficiency requirement in the procurement documents.
FCB-7	Efficiency	Tank-to-wheel efficiency >42%, on the SORT 1 & 2 drive cycles.	>42% on SORT 1 & 2 to be required by the specification and demonstrated by suppliers as part of their factory sign off.
FCB-8	Vehicle capex	€650,000 per standard single deck 12m bus and €1,000,000 for articulated buses.	Tenders will require capex below €650k for a base 12m bus, excluding additional parts (CCTV, extra doors, Wi-Fi etc.). Articulated bus tenders will require capex below €1m.
FCB-9	Vehicle opex	No target.	Maximum of 100% more than an equivalent cost of maintaining a diesel bus, aiming at 50% more by the end of the project.

Table 1.2 Data points for monitoring FC bus operation.

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	Reference
1.1	Hours of bus operation	h	Daily	Alternatively, this can be provided via time stamps for ignition on/off [dd/mm/yyyy] [hh:mm:ss].	T
1.2	Operating hours FC system	h	Daily and per FC system if more than one system installed	Depending on the operating regime implemented by the vehicle OEM the values for this data point may be lower than the values recorded for data point 1.1	T
1.3	Operating hours on route	h	Daily	Optional for operators using this metric	
1.4	Distance driven	km	Daily		T
1.5	Driven distance on route	km	Daily	Optional for operators using this metric	
1.6	Odometer reading	km	monthly		
1.7	Route/ run number	#	Daily		
1.8	Electricity generation FC system	kWh	Daily		
1.9	Electricity consumption electric engine	kWh	Daily	If available, for determining energy consumption for traction	
1.10	Electricity generation electric engine	kWh	Daily	If available, for determining recuperation energy	
1.11	Electricity consumption HVAC	kWh	Daily	If available, separated by heating and AC and for driver and passenger cabin (if separate)	
1.12	Availability status: Out of service	[dd/mm/yyyy] [hh:mm:ss]	Event based	Timestamp for transfer to workshop (out of service message)	
1.13	Availability status: Back to service	[dd/mm/yyyy] [hh:mm:ss]	Event based	Timestamp for transfer back to operations (back to service message)	
1.14	Reason(s) for Downtime		Event based	Linked to 1.12, please give reason for downtime and/ or select from provided list; if multiple downtime reasons please provide (estimated) share of downtime for each reason	

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	Reference
1.14.1	Downtime for scheduled maintenance/upgrades SMU	-	Event based		T
1.14.2	Downtime due to FC stack issues	-	Event based		T
1.14.3	Downtime due to FC balance of plant	-	Event based	e.g. humidifier, air compressor	
1.14.4	Downtime due to electrical components	-	Event based	e.g. electric engine, steering pump	T
1.14.5	Downtime due to the on-board hydrogen storage tank	-	Event based		T
1.14.6	Downtime due to the high voltage battery	-	Event based		T
1.14.7	Downtime due to peripheral mechanical components	-	Event based	e.g. doors, suspension	T
1.15	Repair time	h	Event based	If available from Maintenance system. Actual labour time spent for carried out maintenance/ repairs specified in 1.12.	
1.16	Road call	[dd/mm/yyyy] [hh:mm:ss]	Event based	Indicates unplanned termination of service due to a failure with date and time stamp. Please specify reason for road call	
1.17	Incidents	[dd/mm/yyyy] [hh:mm:ss]	Event based	If yes, information with time stamp and classification according to provided list below. In addition safety incident reporting to be carried out according to 1.18, not required for “regular” traffic accident w/o injury	T
1.17.1	Event type 1: Vehicle incident/ injury/ H2 release	-	Event based		
1.17.2	Event type 2: Vehicle incident/ injury/ no H2 release	-	Event based		
1.17.3	Event type 3: Vehicle incident/ no injury/ H2 release	-	Event based		
1.17.4	Event type 4: Vehicle incident/ no injury/	-	Event based		

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	Reference
	no H2 release				
1.17.5	Event type 5: Near Miss	-	Event based		
1.18	Safety Incident Reporting	Form Sheet	Event based	Reporting for EU HIAD database via separate questionnaire, if safety relevance indicated under 2.16	
1.19	Hydrogen consumption	kg	Daily	Measured on the bus, will be used to cross check with H2 refuelling data (data points 2.1, 2.3)	
1.20	Operational and Maintenance Cost	EUR/ local currency	Every 6 months	Incl. material and labour, excl. fuel cost (see 2.11) and VAT	

Table 1.3 Data points for monitoring FC bus refuelling and recharging

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	Reference
2.1	Hydrogen refuelled	kg	Event based		T
2.2	Station ID	-	Event based	If available	
2.3	Odometer reading	km	Event based		T
2.4	Start of refueling process	dd.mm.yyyy hh:mm:ss	Event based		
2.5	End of refueling process (end)	dd.mm.yyyy hh:mm:ss	Event based	Alternatively duration of refueling process is tracked in [mm:ss]	
2.6	Ambient temperature	°C	Event based	at start of refuelling	
2.7	Vehicle tank temperature at start of refuelling	°C	Event based	Please specify once where the temperature is measured, e.g. using a witness tank	
2.8	Vehicle tank temperature at end of refuelling	°C	Event based		

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	Reference
2.9	Vehicle tank pressure at start of refuelling	bar	Event based		
2.10	Vehicle tank pressure at end of refuelling	bar	Event based		
2.11	H2 Fuel cost	EUR or local currency/l or kg	Once / if changed	Average H2 fuel cost excl. VAT	
2.12	Electricity consumption during (overnight) parking	kWh	Daily	If applicable, e.g. anti-freeze protection, cabin heating, HV battery balancing collection frequency depends on where the electricity consumption is measured: daily – if measured from the vehicle side, monthly – if measured from the infrastructure side	
2.13	Electricity charged	kWh	Event based	If external HV battery recharging capability	
2.14	Start SOC	%	Event based	If external HV battery recharging capability	
2.15	End SOC	%	Event based	If external HV battery recharging capability	

Table 1.4 Data points for monitoring reference bus operation.

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	References
3.1	Hours of bus operation	h	Daily	Alternatively, this can be provided via time stamps for ignition on/off [dd/mm/yyyy] [hh:mm:ss].	T
3.2	Distance driven	km	Daily		T
3.3	Driven distance on route	km	Daily	Optional for operators using this metric	
3.4	Odometer reading	km	Monthly		
3.5	Route/ run number	#	Daily		
3.6	Availability status: Out of service	dd/mm/yyyy	Event based	Timestamp for transfer to workshop (out of service	

FCB Data point no.	Data point	Unit	Frequency of Collection	Comments	References
		hh:mm:ss		message)	
3.7	Availability status: Back to service	dd/mm/yyyy hh:mm:ss	Event based	Timestamp for transfer back to operations (back to service message)	
3.8	Reason(s) for Downtime		Event based	Linked to 3.6, please give reason for downtime and/ or select from provided list; if multiple downtime reasons please provide (estimated) share of downtime for each reason	T
3.8.1	Downtime for scheduled maintenance/upgrades SMU	-	Event based		T
3.8.2	Downtime due to electrical components	-	Event based	e.g. electrical air compressor, steering pump, if applicable	T
3.8.3	Downtime due to peripheral mechanical components	-	Event based	e.g. doors, suspension	T
3.9	Repair time	h	Event based	If available from Maintenance system. Actual labour time spent for carried out maintenance/ repairs specified in 3.6	
3.10	Road call	dd/mm/yyyy hh:mm:ss	Event based	Indicates unplanned termination of service due to a failure with date and time stamp. Please specify reason for road call	
3.11	Diesel / CNG refuelled	l / kg	Event based	litres of diesel or kg of CNG	
3.12	Odometer reading at refuelling	km	Event based		
3.13	Fuel cost	€ or local currency/ l or kg	Once / if changed	Average fuel cost excl. VAT	
3.14	Operational and Maintenance Cost	EUR/ local currency	Every 6 months	Incl. material and labour, excl. fuel cost (see 3.13) and VAT	

Table 1.5 Performance indicators of FC bus operation.

Performance indicator number	Performance indicator	Unit	Period	Parameters and data points required	Comments	Reference
FCB-PI.1 (**KPI FCB-4**)	**Availability** of bus	%	Monthly, annually and overall	1.12, 1.13	KPI target is > 90% See section **Error! Reference source not found.** for details	T
FCB-PI.2 (**KPI FCB-5**)	Mean distance between failures (MDBF)	Km	Annually and overall	1.4 and count of 1.12	KPI target is >2,500 km See section **Error! Reference source not found.** for details	T
FCB-PI.3	Mean distance between road calls (MDRC)	km	Annually and overall	1.4 and count of 1.16	An MDRC of >tbd km (after the teething period) is expected for the JIVE project.	
FCB-PI.4	Distribution downtime hours with respect to root causes	%	Annually and overall	1.14.1 to 1.14.7	The causes for downtime are categorised, distinguishing between the provided categories	
FCB-PI 5	Ratio between actual repair time and Downtime	%	Annually and overall	1.14.1 to 1.14.7, 1.15	This PI will allow to elaborate e.g. on waiting time for support, parts in comparison to reference buses	
FCB-PI.6	TRL	-	Start/ middle/ end of project	FCB.8		T
FCB-PI.7 (**KPI FCB-2**)	**Distance travelled**	km	Monthly, annually and overall	1.4	KPI target is average annual distance of 44,000 km per bus See section **Error! Reference source not found.** for details	T
FCB-PI.8 (**KPI FCB-6**)	Specific **fuel consumption**	kg H2/ 100 km	Monthly, annually and overall	2.1/ 1.19, 2.3	KPI target is in average < 9 kg H2/100 km See section **Error! Reference source not found.** for details. If both data points 1.19 and 2.1 are available, this PI will be calculated for both data points and used for cross-checking	T

Performance indicator number	Performance indicator	Unit	Period	Parameters and data points required	Comments	Reference
FCB-PI.9	Deviation of refuelling data	%	Annually and overall	2.1/ 1.19, 2.3	If data points 2.1 and 1.19 are available ratio between Specific fuel consumption using each of the two H2 refuelled data points	
FCB-PI.10 (**KPI FCB-7**)	**Efficiency**	%	Once	FCB.P21.1/.2	KPI target is > 42% See section **Error! Reference source not found.** for details	
FCB-PI.11 (**KPI FCB-1**)	Vehicle operation **lifetime**	years	Once	FCB.P22	KPI target is > 25.000 h See section **Error! Reference source not found.** for details	T
FCB-PI.12 (**KPI FCB-3**)	Operating hours per fuel cell system	hours	Monthly, annually and overall	1.2	KPI target is > 15.000 h See section **Error! Reference source not found.** for details	T
FCB-PI.13 (**KPI FCB-8**)	**CAPEX**	EUR	Once	FCB-32	KPI target < 650 k€ for 12 m bus, < 1 M€ for 18m bus (excl. operator specific equipment. and taxes) See section **Error! Reference source not found.** for details.	T
FCB-PI.14 (**KPI FCB-9**)	**OPEX**	EUR/km	Annually and overall	1.4, 1.20, 2.11, FCB.P36, FCB.P37	Maintenance and operation costs, including hydrogen, insurances, running costs (tyres, service, parts and labour), maintenance, repairs. Taxes excluded	T