JIVE/JIVE2/MEHRLIN – Project early results

Towards clean public transportation with fuel cell buses

2nd JIVE 2 CEE hydrogen bus roadshow – 6th October 2023 - Tartu

ZERO EMISSION

Presentation by H2EST

Clean Hydrogen Partnership

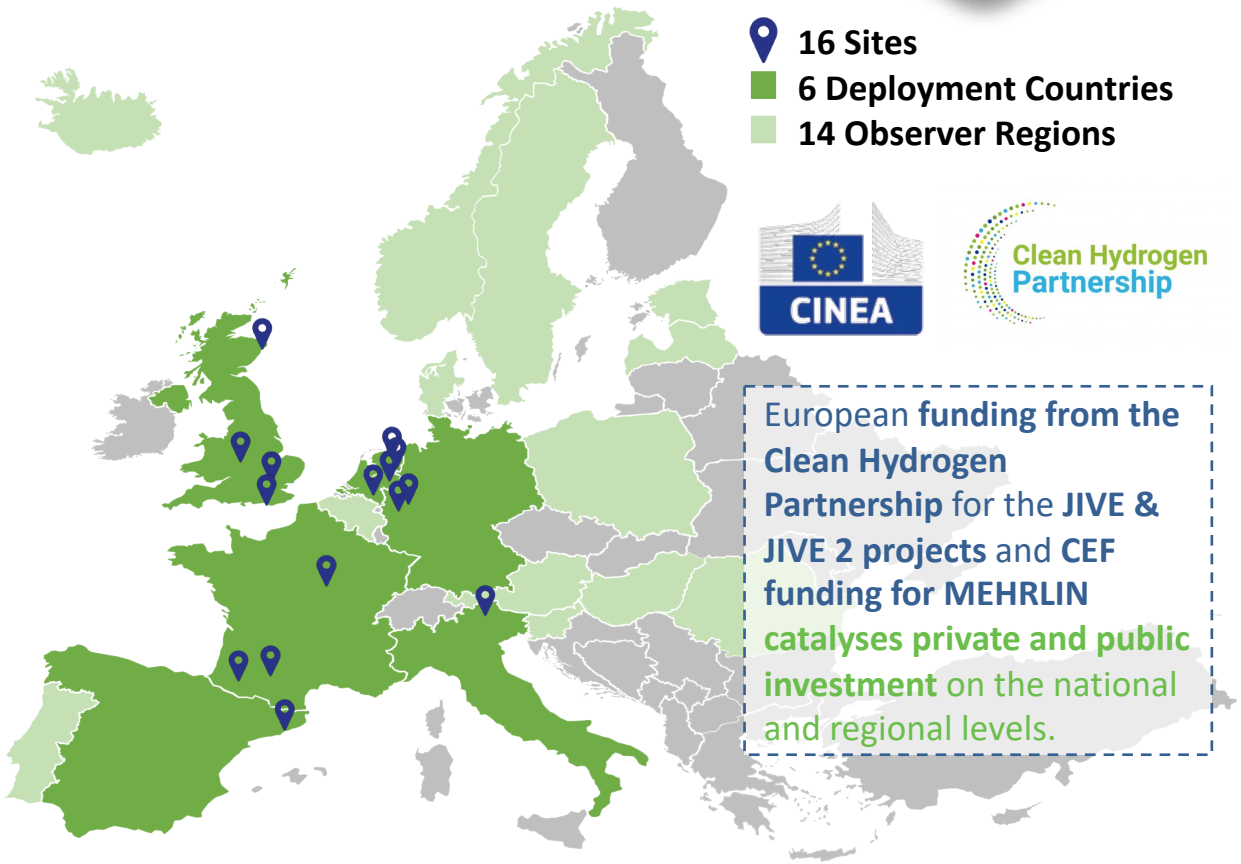
Co-funded by the European Union

The JIVE, JIVE 2 and MEHRLIN projects are the flagship fuel cell bus projects in Europe aiming to deploy c. 300 buses and 18 HRSs by 2025

Objectives:

- **Deploy ~300 buses** across 16 European cities and regions in **6 countries** – the **largest deployment attempted to date**
- Validate large scale fleets in operation
- Stimulate the FCB market
- **Achieve a maximum price of €650k (JIVE) and €625k (JIVE 2)** for a standard fuel cell bus
- Trial joint procurement methods to **access economies of scale**

- **Deploy 18 Hydrogen Refuelling Stations (HRSs)**
- **Enable new cities and regions to trial hydrogen technologies**
- Demonstrate routes to **low cost renewable H_2**
- Analyse the **technical and economic performance of HRSs** under real conditions



Timeline of the 3 projects (JIVE/JIVE2/MEHRLIN)

Overview of the current status with regards to the deployment of the fuel cell buses and hydrogen refuelling stations

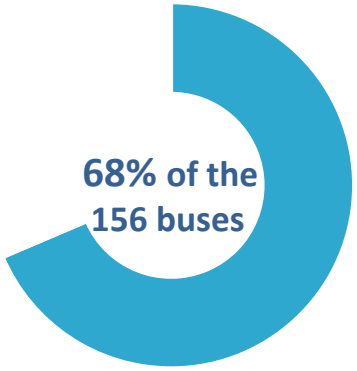
As of end of June 2023, **~82% of the buses have entered into operation** (i.e., 244 buses), and **close to 13M km** have been driven cumulatively.

Regarding hydrogen refuelling stations, **16 were fully operational at the end of June 2023** and **more than 1 million kg of hydrogen were dispensed (>63000 fills)**.

JIVE buses

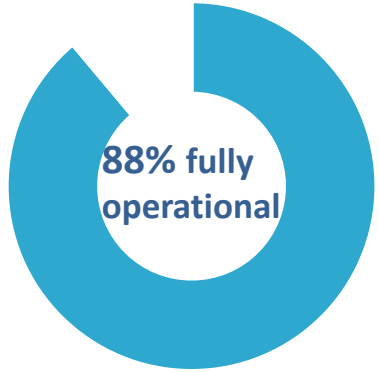
Operational buses Buses not yet operational

JIVE 2 buses



Operational buses Buses not yet operational

Hydrogen refuelling stations (JIVE/JIVE2/MEHRLIN)



Operational HRS HRS not yet fully operational

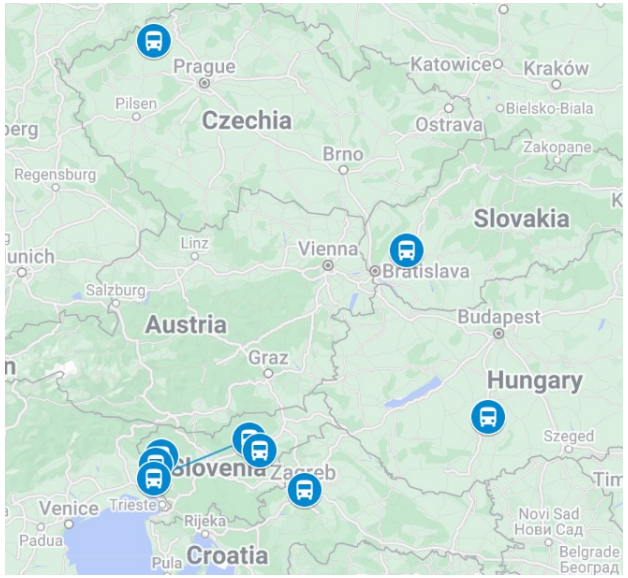
- 5 European OEMs
- Single deck (~67%) and double deck (~33%) buses
- Fleets from 5 to 50+ buses







1st JIVE 2 CEE (Central Eastern European) Roadshow – Successful JIVE 2 initiative that allowed interested cities to test the technology



- **Total distance of 1 641 km** and consuming approximatively **125 kg of H2**, resulting in an **average consumption of 7,6 kg/100km.** Bus has a **range of at least 400 km**
- **13 events** - attended by over **900** participants
- Most of the cities that trialed the technology (**over 90%**) have announced a formal interest in deploying FCBs after the roadshow
- In total, over **150 hydrogen buses** will be deployed in the region over the next years

Overall Coordinator

Hydrogen Europe

National Coordinators

Hungarian Hydrogen and Fuel Cell Association

HYTEP Czech Hydrogen Technology Platform

NVAS Cluster

H2LV

HRVATSKA UDRUGA ZA VODIK
CROATIAN HYDROGEN ASSOCIATION

ECUBES Hydrogen & Flexibility

Infrastructure providers

CaetanoBus

MESSER Gases for Life

Partners

UITP Advancing Public Transport

ERM

Initiative funded by the Clean Hydrogen Partnership

Co-funded by the European Union

Clean Hydrogen Partnership

"The efficiency of hydrogen cells is constantly increasing. Thanks to that hydrogen buses become a reliable alternative to vehicles using diesel. This was also confirmed by the intensive 3-day testing of the CAETANO hydrogen bus on one of the city lines in Trnava."

Mr. Peter Nemec, CEO of Arriva Trnava

Fuel cell buses offer several advantages over conventional and other zero emission technologies. Advantages already proven by the JIVE projects

High daily range

Up to 500 km without refuelling satisfies the longest routes and provides **operational resilience**

Project results

JIVE and JIVE 2 buses have demonstrated ranges of >350 km. Models have since been made available claiming higher ranges.

1st JIVE 2 CEE bus roadshow results

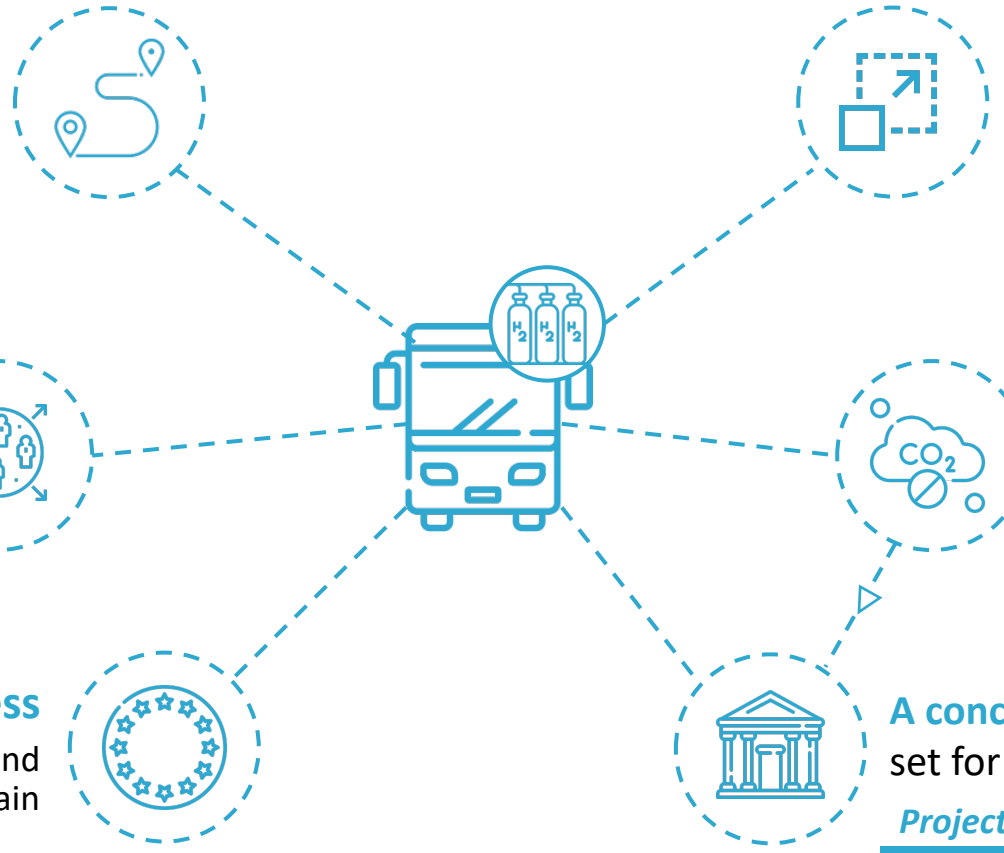
Range of at least 400km - – estimated that could be approx. 500km in the flat city of Paks.

Increased passenger capacity

18m and **double decker** models now widely available

Enhance European competitiveness

Due to the European manufacturing base and the supply chain



Scalability

The refuelling infrastructure can be **scaled up** to accommodate **growing fleets**

Project results

Most of the transport operators within the JIVE/JIVE 2/MEHRLIN projects have already ordered further hydrogen buses or are aiming to increase their hydrogen bus fleet in the next years – in some cases this requires little to no station update

Zero tailpipe emissions

As fuel cell buses **operate locally emission free**, of a pure fuel cell bus fleet would result in the **complete avoidance of combustion nitrogen oxides** and **particulate matter emissions**

A concrete answer to ambitious policy targets set for transport decarbonisation

Project results

*With hydrogen from electrolysis using electricity from wind power throughout the JIVE sites, **an overall Global Warming Potential reduction of 82% can be achieved****

**Environmental Impacts and External Costs Benefits of FCBs – Comp. of FCBs with BEBs (Sphera) – JIVE (D3.22) / JIVE 2 (D3.6/D4.3)*

Performance of the buses (fuel consumption) – buses are outperforming the project objectives

Specific Fuel Consumption

<9 kg/100 km (standard buses)
<14 kg/100 km (articulated buses)

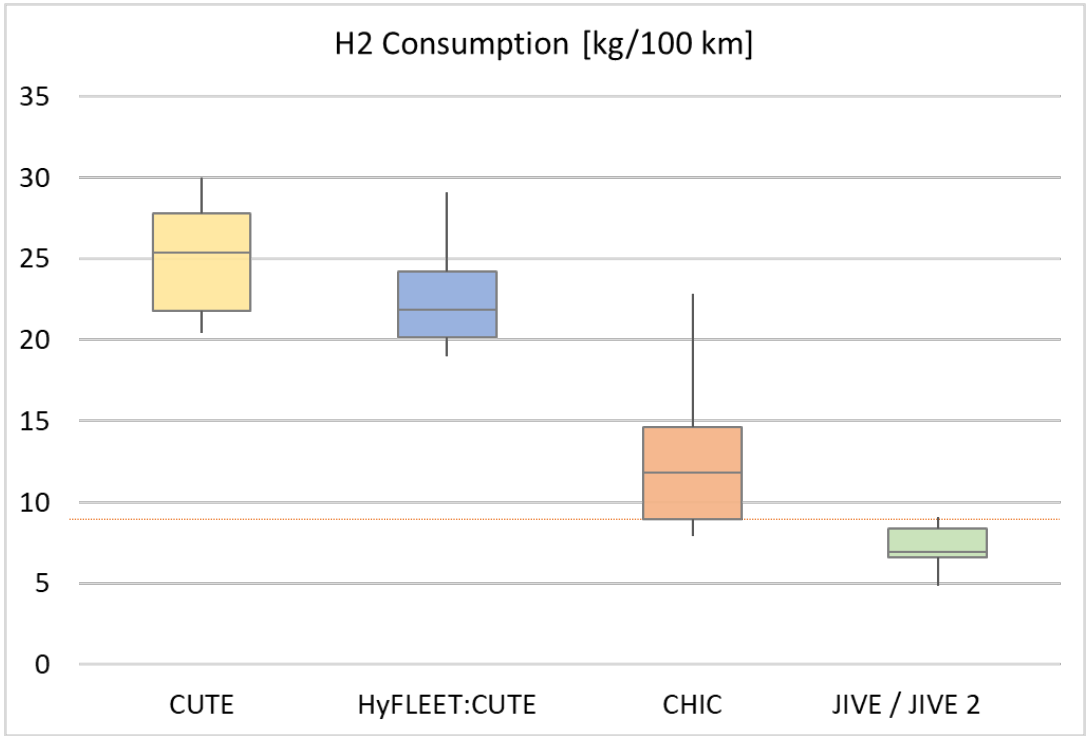
✓ *Target achieved at present*

- Excellent fuel efficiency with consumptions currently between **6.3 and 9 kg of hydrogen per 100 km for 12 m and double decker buses** (equivalent to between 20 and 23 litres of diesel) and **less than 9 kg per 100 km for 18 m articulated buses** (equivalent to less than 30 litres of diesel).
  - **Buses are outperforming the objectives**.

- **Significant reduction in fuel consumption over the projects** (see chart)

Results from the 1st roadshow

- Average consumption of **7.6 kg/100km**



Total numbers deployed / to be deployed in the projects

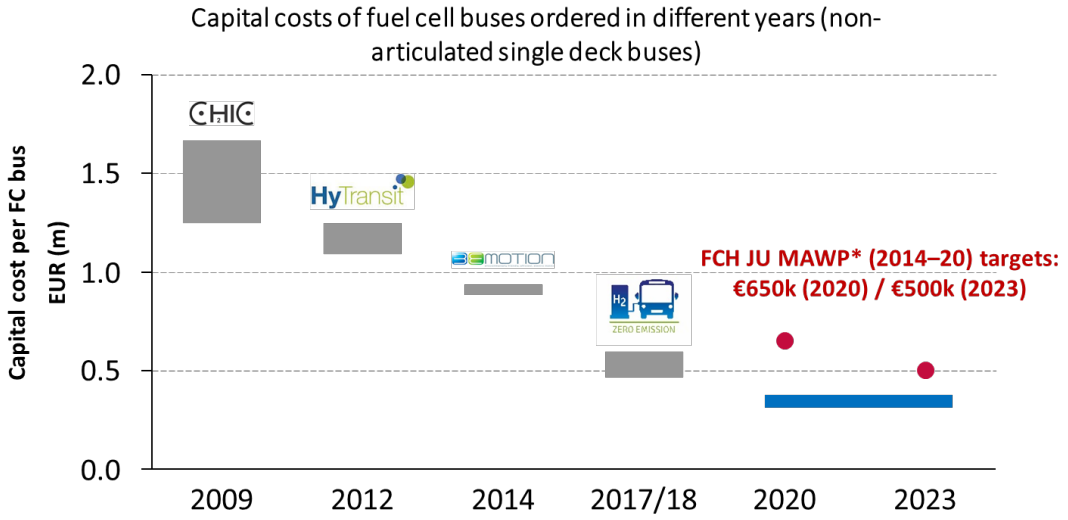
27 FCBS	47 FCBS	54 FCBS	298 FCBS

** Data up to 2022. The JIVE and JIVE 2 projects will run until June 2024 and June 2025 respectively; not all buses are therefore yet operational.*

Drop in bus prices (CAPEX) compared to previous FCB projects

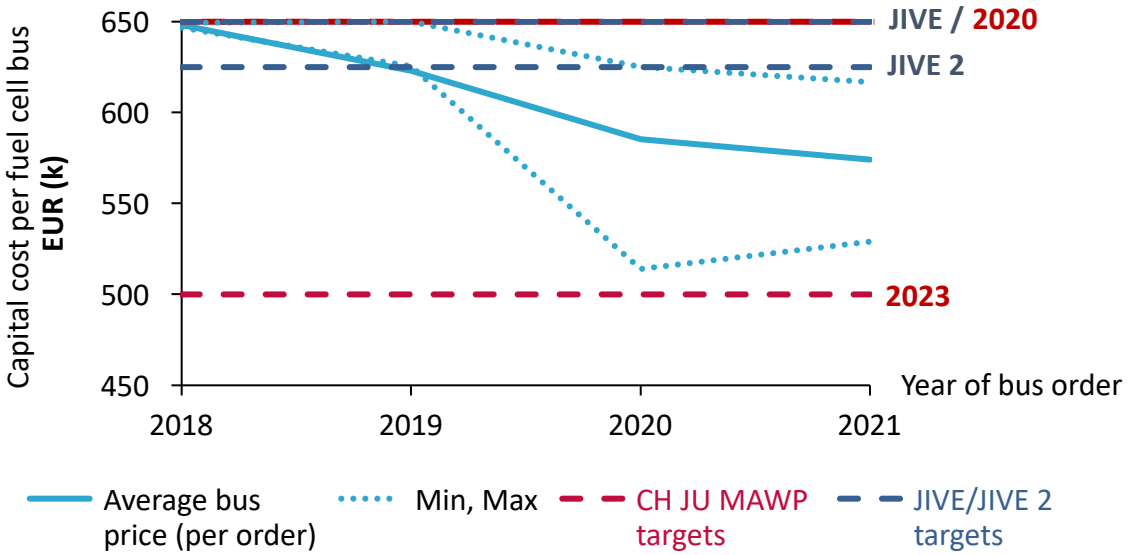
The prices of the buses purchased under JIVE and JIVE 2 have significantly decreased compared to previous projects.

Actual bus capex – historic FCB projects



Prices have significantly decreased since the first funded FCB projects, a success of the increasing scale of the JIVE deployments.

Actual bus capex – JIVE & JIVE 2



Minimum costs are accessible for vehicle orders of >10 buses. Price varies depending on specifications.

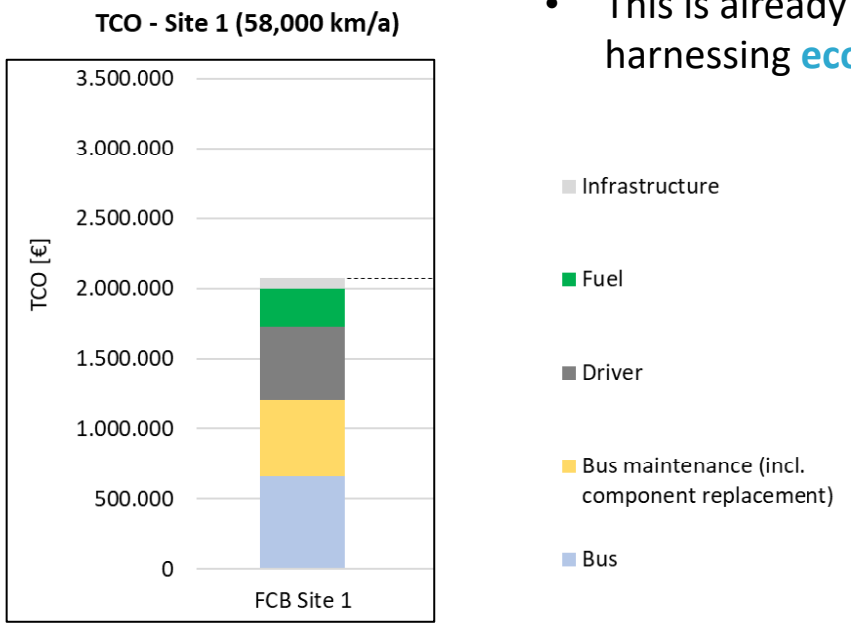
The JIVE and JIVE 2 targets have been achieved. The Clean Hydrogen Partnership 2020 target was achieved early in 2018.

While fuel cell bus costs have fallen significantly, further reductions will be needed for commercially viable offers.

NB: 1) Prices shown are the base bus prices which excludes add-ons such as USB ports, WiFi, lighting, etc.
2) 5 orders were excluded in total: 4 due to data availability, 1 order was for 18m buses

Early results - FCBs systems against economic parameters (TCO analysis)

- **When long and demanding routes shall be served, fuel cell buses are advantageous** in terms of their higher operating range and their flexible deployability, as they can be used flexibly on any route without having to think about recharging options.



Results of the TCO analysis for FCBs at site 1 (Mileage: 58,000 km/a)

- Fuel cell buses therefore offer significant advantages for bus schedules with high range requirements.
- It can be expected that with the ongoing increasing maturity of **FCBs and hydrogen technology** the TCO of FCBs will decrease.
- This is already the case when important orders are made, harnessing **economy of scale effects**.

Disclaimer: Example TCO structure for 1 site - has to be pointed out that the results only depict the situation at one of the two sites investigated, and do not allow any general statement

Existing resources/initiatives within the JIVE projects to help transport operators interested in the technology

JIVE User Group: Objectives, composition and format

- **Main Goal:** Exchange feedback and discuss operational assessment from the point of view of external PTO/PTAs to JIVE deployment sites
- **Composition:** Around 20 PTOs/PTAs interested in Fuel Cell Technology and deployment and integration of FC Buses in their fleet
- **Format:** it follows JIVE projects' results in terms of bus performance, service quality, operations, maintenance, and other relevant aspects related to fuel cell bus technology through dedicated meetings (2 per year).
- **Participation:** the experts benefits from a lump sum of 560 euros per meeting to support his/ her participation in the User Group meetings through a contract.
- **Events:** Meetings are aligned with relevant PT events or technical visits.

JIVE/JIVE2/MEHRLIN Best Practice report

- Available on the project website (here) – 100 page document with all the learnings of the projects divided in the project life phases:

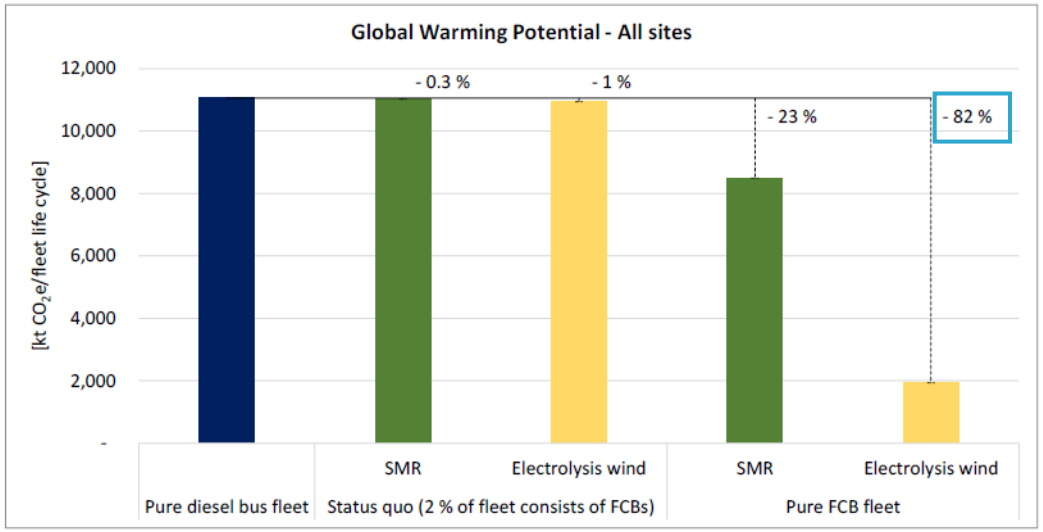
1) Stage 1 – Project Conceptualisation
2) Stage 2 – Financing and Planning
3) Stage 3 – Procurement
4) Stage 4 – Deployment and Operations

- A Case Study was developed (section "Bringing it all Together") with info boxes that summarise the essentials for a successful FCB deployment project

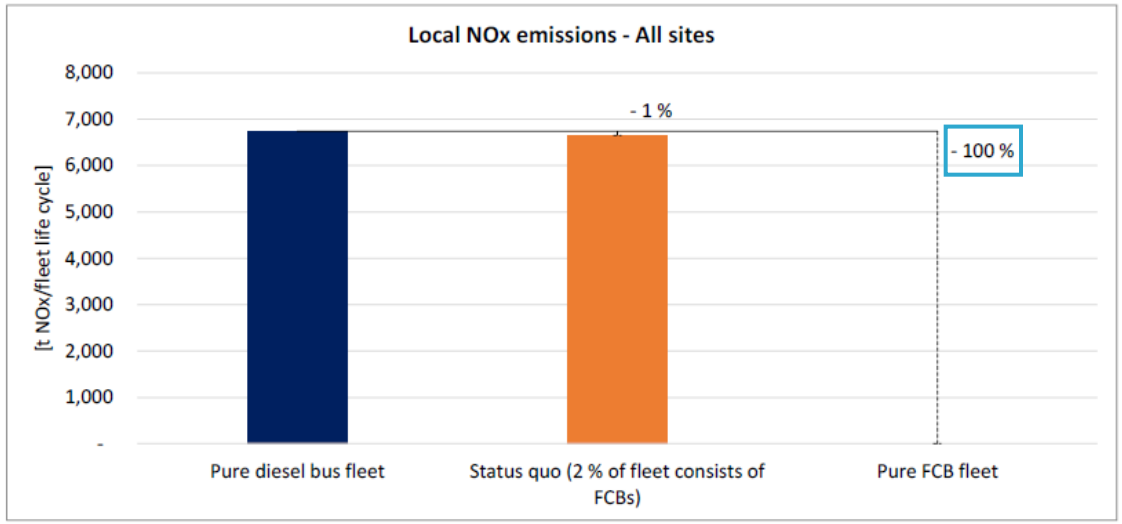
Early results on environmental impacts and external cost benefits of FCBs systems

Results on avoided environmental impacts

- **The hydrogen production by electrolysis using electricity from wind power** results in the **lowest external cost**.
- With hydrogen from electrolysis using electricity from wind power throughout the JIVE sites, an overall **Global Warming Potential (GWP) reduction of 82% can be achieved**.



Global Warming Potential for diesel bus replacement by FCBs – All sites



Local NOx emissions– All sites / Same graph for PM 2.5 emissions

The projects are yet to be finished; 1st findings show general target feasibility but also highlight room for improvement

Bus Performance

Distance travelled
JIVE: min. 132,000km/bus in 3 years
JIVE 2: min. 150,000km/bus in 3 years

Availability of Buses
>90%

Specific Fuel Consumption
<9kg/100km (standard buses)
<14kg/100km (articulated buses)

HRS Performance

Availability of Station Unit
>98%

Amount of Hydrogen Dispensed
JIVE: >4,500kg/bus/year

- **Comparison with past projects** – Buses and refuelling stations in JIVE/JIVE 2 have, overall, the potential to outperform their counterparts or have already done so.
- **Teething periods** – JIVE/JIVE 2 local bus fleets did not exhibit pronounced teething periods, unlike in earlier projects.
- JIVE/JIVE2 local fleet are no longer considered a potential "add on" to normal operations by operators but **part of day-to-day-service**.

Target feasibility

- Target achieved at present
- Room for improvement – several sites are already close to reaching this target

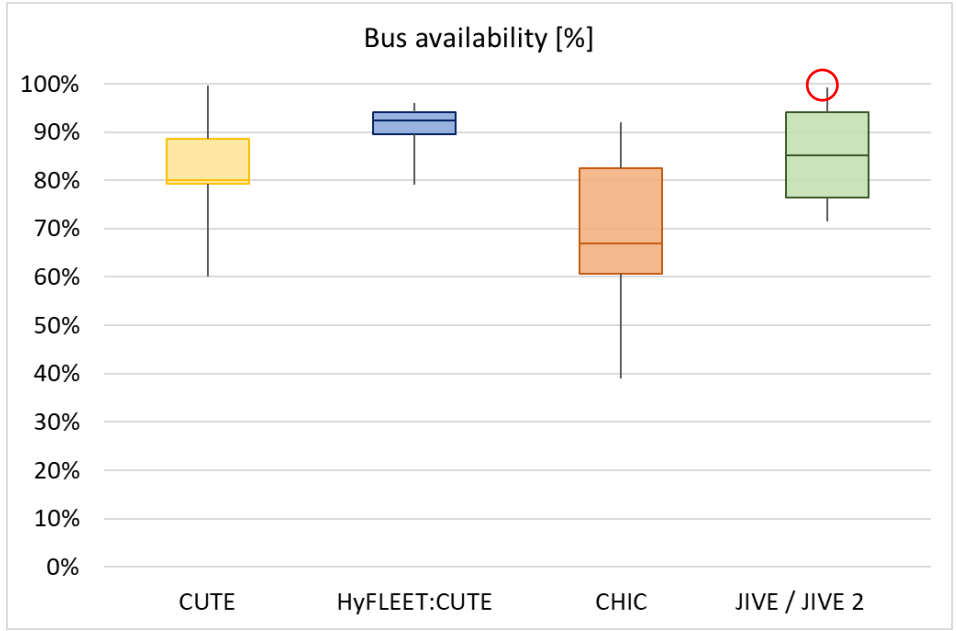
Performance analysis was conducted by Sphera and PLANET

Performance of the Buses (Availability) – Good performance in general

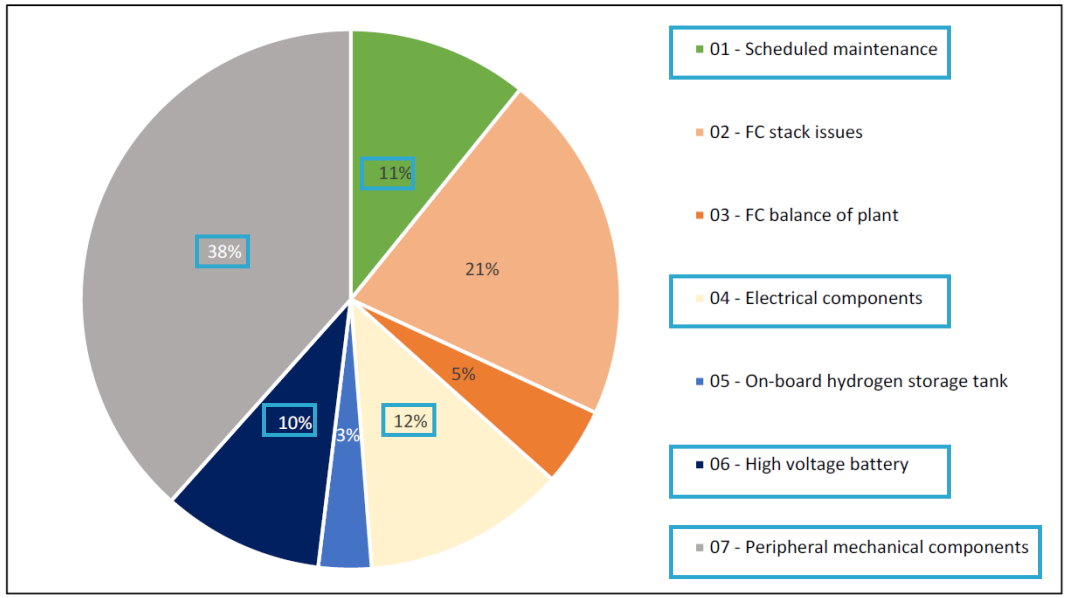
Availability

>90%

- **Buses from all manufacturers** represented in the projects have **proven the capability to surpass the 90% target during some parts of the reporting period**. The fleet averages at five sites are higher than 90%. **Single sites have reached 99% availability**.
- **Average availability** across all JIVE sites **~85 % at the end of 2022**.



- Analysis shows that often non-hydrogen related components cause more than half of the downtimes



Downtime reasons FCBs – Based on data from JIVE projects

** Data up to 2022 ; not all buses are therefore yet operational. The JIVE and JIVE 2 projects will run until June 2024 and June 2025 respectively.*

Use-case Estonia

- Tallinn 5.9 kg / 100 km (ametlik spec 5.5kg/100km)
- H2 hind Tallinna tanklas ~10 € / kg
- 1 km hind = ~0.59 €
- 64 PAX = 0.009 € PAX KM
- H2 90k km/a = 5.3 tpa = 53.1k€
- CNG 90k km/a = 36 tpa = 43.2k€ =
- CNG CO2e 98.9 tpa = 9890€ @ 100€/t CO2
- With climate price = price parity?
- With health price = ?