JIVE, JIVE 2 & MEHRLIN - Project Conclusions

by ERM, based on the contributions and results generated by all project partners

Prepared in 2025. Finalised version: May 2026

ZERO EMISSION

JIVEs / MEHRLIN projects

Clean Hydrogen Partnership

Co-funded by the European Union

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This document summarises the key results, learnings and takeaways of the JIVE, JIVE 2 & MEHRLIN projects

JIVE, JIVE 2 & MEHRLIN were three interconnected European flagship projects supporting the **decarbonisation of public transport** through the deployment of **hydrogen refuelling stations and fuel cell bus fleets** across multiple cities. Co-funded by CINEA and the Clean Hydrogen Partnership, they have played a critical role in advancing hydrogen mobility in Europe, showcasing how cross-border collaboration can drive the transition to cleaner transport.

With JIVE 2 having concluded in 2025, this document provides:

- A summary of the projects and their key results
- Insights from real-world implementation for stakeholders
- Lessons learned and common themes to guide future hydrogen mobility initiatives

Co-financed by the Connecting Europe Facility of the European Union

Co-funded by the European Union

Glossary of acronyms

BEB	Battery-electric bus(es)
CH JU	Clean Hydrogen Joint Undertaking/Clean Hydrogen Partnership
FCB	Fuel cell bus(es) - a zero-emission bus powered by hydrogen fuel cells
GWP	Global warming potential
HRS	Hydrogen refuelling station(s)
LCA	Life cycle assessment
JIVE	“Joint Initiative for Hydrogen Vehicles Across Europe”
MEHRLIN	“Models for Economic Hydrogen Refuelling Infrastructure”
OEM	Original equipment manufacturer
PTO	Public transport operator
PTA	Public transport authority
TCO	Total cost of ownership
ZEB Conference	Zero Emission Bus Conference

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The MEHRLIN and JIVE projects set out to accelerate the deployment of hydrogen mobility in Europe

What is MEHRLIN?

MEHRLIN (Models for Economic Hydrogen Refuelling Infrastructure) sought to demonstrate a **financeable, demand-led business model** for hydrogen refuelling stations, further **boosting the deployment of hydrogen** as an alternative fuel in the EU.

The project aimed to achieve this goal by **deploying and operating large stations**, coupled with detailed analysis of their **technical and economic performances**.

The project was funded via the **Connecting Europe Facility (CEF) programme**, implemented by **CINEA**.

Co-financed by the Connecting Europe Facility of the European Union

What are JIVE & JIVE 2?

The JIVE (Joint Initiative for Hydrogen Vehicles in Europe) projects aimed to advance the commercialisation of fuel cell buses (FCB).

Through **large-scale deployment of vehicles and infrastructure**, the goal was to make FCB **commercially viable** for bus operators without subsidy, and for local and national governments to be empowered to **regulate for zero emission propulsion** in their public transport systems.

Funded by the **Clean Hydrogen Partnership,** successor of the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU).

Co-funded by the European Union

These projects built on earlier European fuel cell bus initiatives but took deployment to the next level

H_2 ZERO EMISSION

MEHRLIN and the JIVE projects built on the foundation of preceding European FCB deployment initiatives — but stand out as the largest and most ambitious to date.

CHIC
26 FCB
2010 - 2016

HIGHVLOCITY
14 FCB and 3 HRS
2012 - 2019

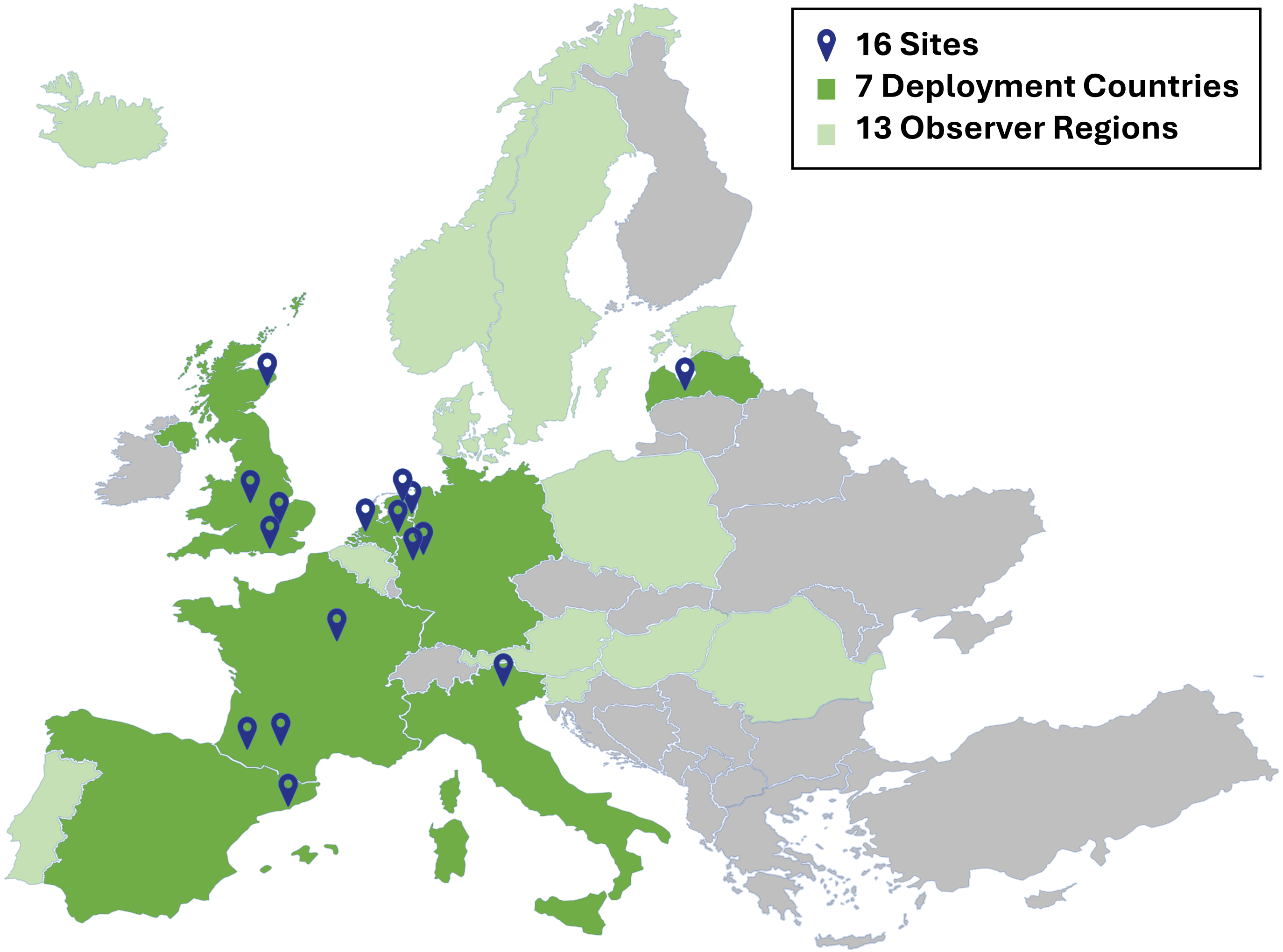
HyTransit
6 FCB, 1 HRS
2013 - 2019

3EMOTION environmentally friendly, efficient, electric motion
21 FCB
2015 - 2022

JIVE, JIVE 2 and MEHRLIN
JIVEs / MEHRLIN projects
H_2 ZERO EMISSION
290+ FCB, 17 HRS
2016 - 2025

SCALING UP

Together, MEHRLIN and the JIVE projects created a pan-European FCB ecosystem



Together, the three projects played a leading role in the promotion of hydrogen mobility in public transport by addressing two critical elements: **fuelling infrastructure and vehicles**.

MEHRLIN, JIVE and JIVE 2 mostly ran alongside each other, jointly deploying

- **17 HRS,** and
- **290+ FCB**, the largest deployment in Europe to date,
- Across **16 sites and 7 countries.**

The coordination between vehicle deployment and infrastructure was key in **fostering hydrogen ecosystems** - several buses funded under JIVE refuel at MEHRLIN stations.

Two sites in Germany, Cologne and Wuppertal, participated in all three projects.

This was made possible by a diverse consortium of cities, operators, and industry players

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Deployment partners (PTO, PTA, municipalities, industry)

Supporting partners (coordination, analysis, experts, industry)

The success of MEHRLIN, JIVE & JIVE 2 was made possible by the **collaboration of more than 35 partners** from across Europe.

Spanning a wide range of qualifications, every consortium member had a role to play in the projects' accomplishments – from public transport operators and authorities, to municipalities, industry leaders, sector experts, as well as supporting partners.

By combining their knowledge and competencies from planning to implementation, partners engaged in frequent exchanges throughout the project, providing opportunities to **share insights, lessons and learnings and to jointly tackle the challenges of hydrogen mobility**.

A wide range of suppliers delivered the technical solutions to the projects

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A **diverse range of suppliers** contributed to the MEHRLIN and JIVE projects, providing the equipment (FCB & HRS) and hydrogen necessary to the deployment of the projects and participating in exchanges with the Consortium.

Throughout the projects, several OEMs (Original Equipment Manufacturers) emerged as frontrunners in the hydrogen mobility market. **Participating OEMs further developed their expertise** through these initiatives, leading to new and upgraded solutions.

During the years of the projects, new players emerged on the hydrogen scene, increasing the number of offerings on the market compared to the start of the project.

H_2 & HRS suppliers

JIVE, JIVE 2 & MEHRLIN H_2 suppliers & HRS OEMs

Other European H_2 suppliers & HRS OEMs

FCB suppliers

JIVE & JIVE 2 bus OEMs

Other European bus OEMs

Non-European bus OEMs

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5-minute summary: An overview of MEHRLIN

Key objectives

- **Build/upgrade and operate HRS at 7 sites in 4 countries**
- **Collect and analyse real-world data** on technical and economic performance
- **Assess the financing case** for HRS using a demand-led business model
- **Demonstrate environmental and economic performance of HRS**, testing solutions to reduce costs and improve efficiency
- **Launch of dissemination activities**, targeting the general public, policy makers, financiers, etc. to raise awareness about hydrogen and communicate progress.

Achievements

7 new/upgraded HRS in operation

as of June 2023, all reached the target of 12 or 18 months of operation

200t+ of hydrogen refuelled

to support FCB fleets

Report on the economics of the station

published and publicly available here.

60+ site visits and local dissemination activities

throughout the project, organised in 4 countries (Germany, Italy, the Netherlands, UK)

5-minute summary: An overview of JIVE & JIVE 2

H2 ZERO EMISSION

Key objectives

- ☑ Deploy 290+ FCB across 16 European cities
- ☑ Achieve a price of ≤ €650k (JIVE) and ≤ €625k (JIVE 2) per standard bus / ≤ €1m per articulated bus
- ☑ Demonstrate high reliability of FCB (> 90%)
- ☐ Demonstrate high reliability of HRS (> 99%)
- ☐ Demonstrate routes to low cost (< 9€/kg) renewable hydrogen
- ☑ Deliver positive environmental impacts
- ☑ Provide evidence of the technical and commercial suitability of fuel cell buses for further roll-out
- ☑ Stimulate further uptake of FCB

Achievements

Extensive data gathered and analysed

confirming strong overall bus performance, including excellent fuel efficiency across diverse conditions.

First-of-a-kind deployments

Barcelona was Spain's first city to incorporate FCB into their fleet, Pau the first to deploy 18m FCB, Brighton & Cologne Europe's first regions with 50+ FCB.

Wide variety of bus models deployed

including standard, articulated, single- & double-decker buses with an array of configurations and applications.

Actively sharing key learnings with the sector

through ZEB conferences, social media campaigns, JIVE User Group meetings & public presentations, and four FCB roadshows.

5-minute summary: Key results & learnings from the projects

Results & learnings: Fuel cell buses

FCB are capable of **meeting operators' expectations** in terms of **distance travelled,** and in many cases, **reliability,** which improved strongly during the projects.	A significant part of the **FCB downtime was linked to non-hydrogen issues,** e.g., spare part supply shortage and maintenance delays.	In JIVE and JIVE 2, the **FCB price targets** of €650K and €625K respectively **were achieved.**	**A fuel efficiency** of <9 kg/100 km for standard buses and <14 kg/100 km for articulated buses was met.	Potential **use cases where FCB can add value or outperform BEB in Europe** were identified.

Results & learnings: Hydrogen refuelling stations

Sites that have built **redundancy** into their **HRS systems show higher availability levels**, contributing to more reliable support for bus operations.	Station dependability can be improved by **linking HRS operators' and OEMs' revenues to HRS performance/reliability metrics**.	Ensuring that **contracting and tendering are fit for purpose** is key to minimising station downtime. Securing backup solutions is also key.	An HRS's **economic viability** depends on **high utilisation** rates and **sufficient capacity**. High utilisation also enables H_2 costs to get closer to diesel.	The **energy crisis highly impacted H_2 prices** at most sites. At the end of the projects, the higher-than-expected prices remain a barrier for further deployments.

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MEHRLIN focused on tackling Europe's hydrogen refuelling infrastructure gap

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MEHRLIN aimed to address a critical issue in the decarbonisation of (public) transport: the lack of refuelling infrastructure - a key barrier to the deployment and commercialisation of hydrogen as an alternative fuel.

To help mitigate this barrier, MEHRLIN pursued the following objectives and activities:

- ☑ **Build and operate HRS at 7 sites in 4 countries**:
  - ☑ Germany: Wuppertal, Wermelskirchen (Cologne) & Hürth
  - ☑ Netherlands: Heinenoord (South Holland)
  - ☑ Italy: Bolzano
  - ☑ United Kingdom: London & Birmingham
- ☑ **Collect and analyse real-world data** on technical and economic performance
- ☑ **Assess the financing case** for HRS using a demand-led business model
- ☑ **Demonstrate environmental and economic performance of HRS**, testing solutions to reduce costs and improve efficiency
- ☑ **Launch dissemination activities**, targeting the general public, policy makers, financiers, etc. to raise awareness about hydrogen and communicate progress.

Bolzano (IT)

South Holland (NL)

London (UK)

From 2016 to 2023, MEHRLIN achieved major milestones contributing to the sector's evolution

7 new/upgraded HRS in operation

as of June 2023, all reached the target of 12 or 18 months of operation

Report on the economics of the stations

published and available here.

200+ tonnes of hydrogen refuelled

to support FCB fleets

60+ site visits and local dissemination activities

throughout the project, organised in 4 countries (Germany, Italy, the Netherlands, UK)


Bolzano


South Holland

London

Wuppertal


Hürth


Birmingham


Cologne

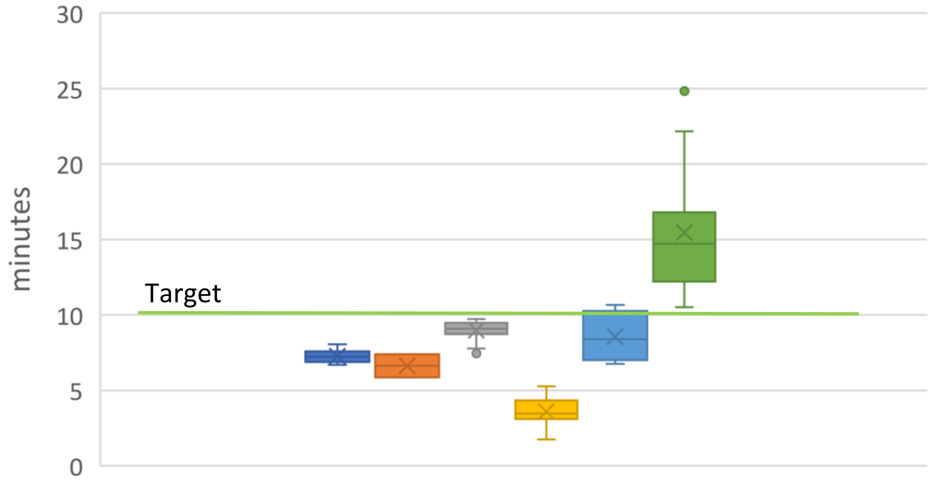
Data collected throughout the project focused on the technical performance of the HRS…

ZERO EMISSION

Collect and analyse real-world data on technical and economic performance

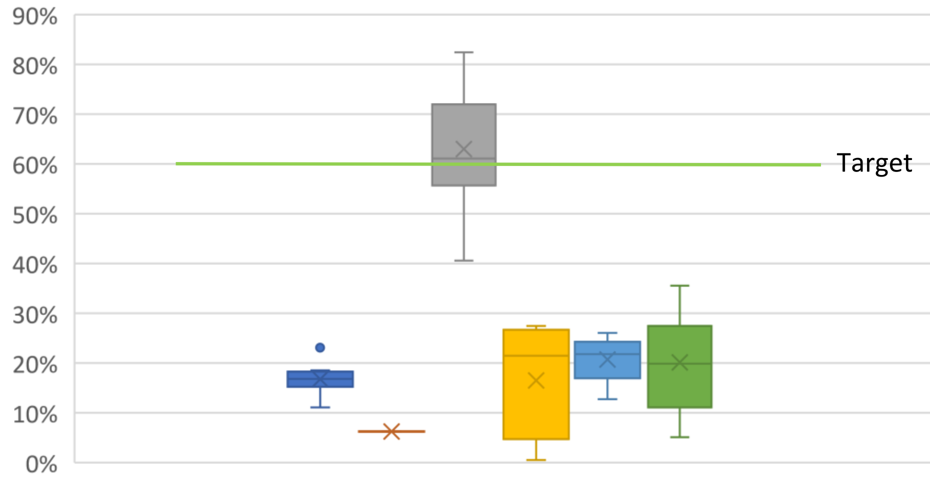
- A smooth refuelling process is essential for ensuring a maximum throughput of hydrogen and achieving a viable business case.
- MEHRLIN set out to achieve 99% HRS availability; by the end of the project an average of 95% was achieved.
- Two key indicators were selected to demonstrate technical HRS performance: refuelling speed per process and utilisation rate per site.

Filling time per site: Achieved



- **Almost all sites met the target of under 10 minutes per fill** at various stages of the project.
- **Most sites consistently outperformed expectations**, with notably faster filling times.

Utilisation rate per site: Not fully achieved



- **The target utilisation rate of over 60% of peak capacity was not fully achieved** - only one site met the target during the project duration.
- **Most HRS were oversized** relative to the actual bus fleet demand.
- **Fleet scale-up is planned** by several operators in the coming years, which is expected to increase utilisation rates.

… as well as on the economic viability of the HRS, highlighting that it depends on high utilisation rates and sufficient station capacity

Collect and analyse real-world data on technical and economic performance

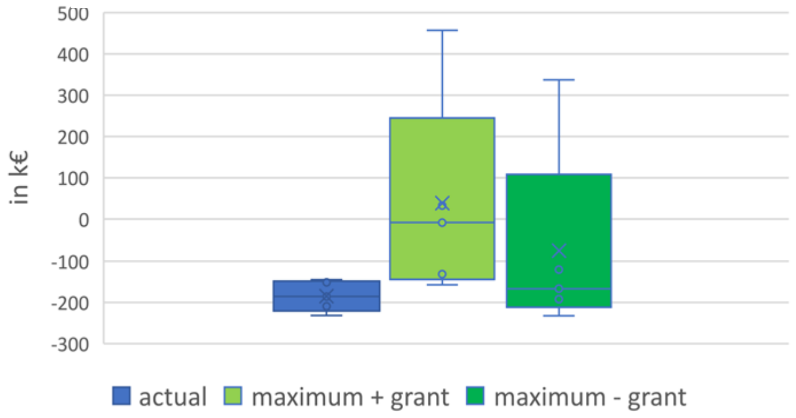
Context of calculations and simulations

- The graphs compare **real economic data over 12 months** (blue bar) **with modelled scenarios** based on maximum utilisation rates (light and dark green bars/dots).
- The analysed MEHRLIN sites **only refuelled the FCB in their area, often operated under JIVE and/or JIVE 2,** and did not sell hydrogen to third parties.
- Since no hydrogen sales prices were realised, the models assumed a **30% margin on the purchase price or production cost of hydrogen**.

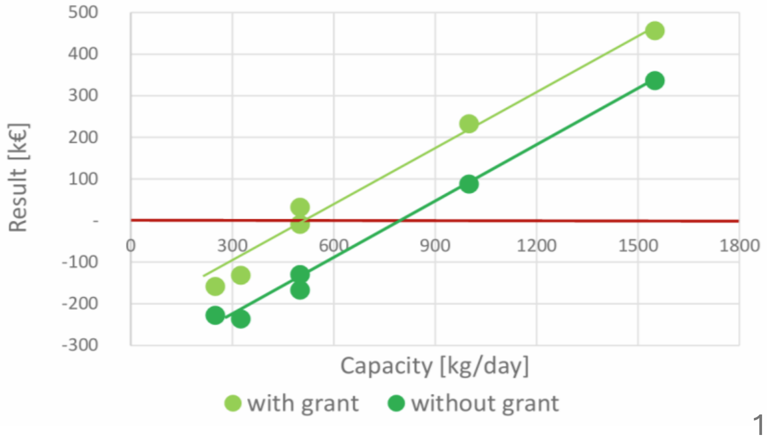
Result: Economic viability depends on both high utilisation and sufficient station capacity

- **No site reached financial breakeven on an annual basis** (based on 12–18 months data), primarily due to **low utilisation rates**.
- In simulations, **some sites reached profitability** - but only at high utilisation rates and above a critical daily capacity:
  - **> 500 kg/day with subsidies**
  - **> 750 kg/day without subsidies**

Economics of MEHRLIN HRS



Break-even: utilisation at full capacity



Data highlighted that the utilisation rate of an HRS is key to bring fuel costs of FCB close to those of diesel buses

Collect and analyse real-world data on technical and economic performance

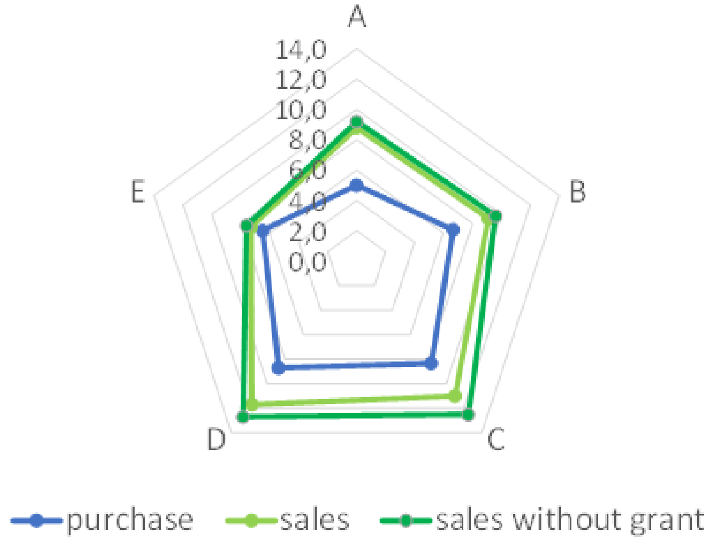
Context of calculations and simulations

- Based on annual costs and revenues, the model calculates the **hydrogen sales price required to break even after five years of operation**, assuming no inflation or cost increases.
- HRS operation at **maximum capacity** is assumed.
- The calculated sales price, along with the average hydrogen consumption of the buses per site, is used to **determine the fuel cost per 100 km**.
- These **results are then compared to the performance of diesel buses**, assuming a diesel consumption of 45 L/100 km at a price of €1.20 per liter.

Result: Fuel costs for FCB approach diesel with high HRS utilisation

- The simulated purchase price per site ranges from **€7.3–11.7/kg with subsidies and €7.6–12.7/kg without**.
- To break even, an average markup of 38% (48% without subsidies) is required.
- On average **the fuel costs for a FCB are 40% higher than for a diesel bus** (50% higher without subsidies).
- Simulations indicate that operating HRS at high capacity could bring fuel costs in line with diesel buses.

Purchase vs. sales price



A-E: 5 of the 7 HRS deployed in MEHRLIN

Overall, MEHRLIN's findings show that scaling up fuel cell bus fleets is critical for a strong business case

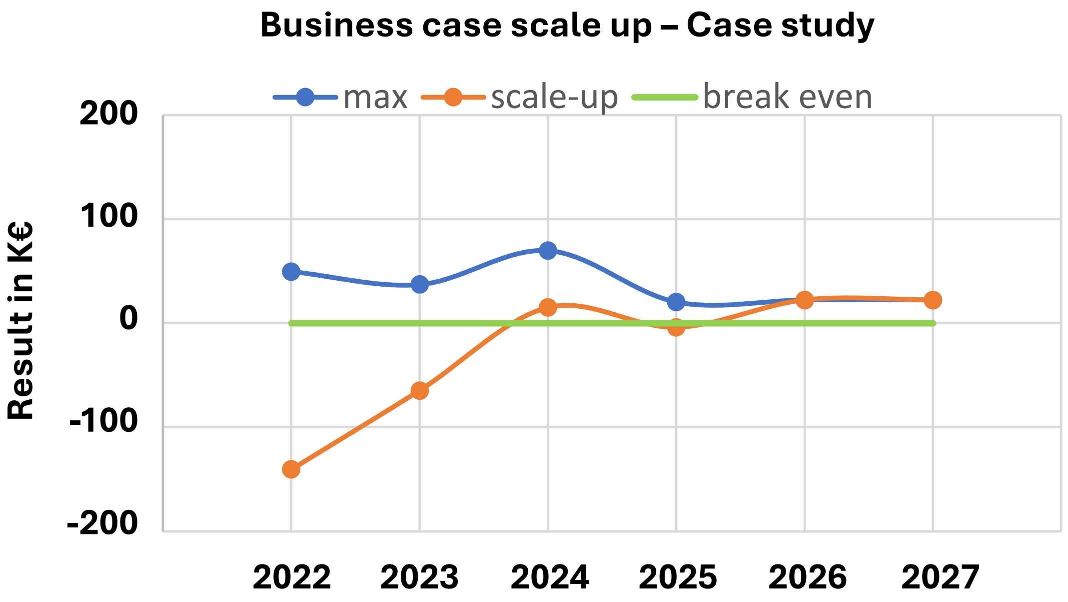
Collect and analyse real-world data on technical and economic performance

Context of calculations and simulations

- Simulations **compare an HRS at full utilisation** (blue line) **with a scale-up scenario starting at 20% utilisation and reaching 100% by 2026** (orange line).
- The scale-up scenario is based on actual data, with planned bus fleet growth of +6 in 2024, +7 in 2025, and +9 in 2026.
- By 2026, HRS utilisation reaches 100%, with 98% availability.
- Results are compared to diesel bus performance (assumed at 45 L/100 km, €1.20/L).

Break-even for HRS operators achievable with continued bus deployment

- The HRS reaches a positive business case with an **increase in bus deployment** and **maximum utilisation** of the HRS.
- The case shows that **32% margin (with subsidies)** is needed on top of the purchase price to break even.
- Under these conditions, the fuel costs for a fuel cell bus are **59% higher** than for a diesel bus.



	2022	2023	2024	2025	2026	2027
Bus deployment	12	12	18	25	34	34
Utilisation rate	56%	100%	100%	100%	100%	100%
Availability	98%	98%	98%	98%	98%	98%

Content

JIVE and JIVE 2's objective was to accelerate the commercialisation of FCB across Europe...

H2 ZERO EMISSION

JIVE and JIVE 2 contributed to the commercialisation of fuel cell buses at scale across Europe with the objective of making them viable for operators without subsidies.

To achieve this goal, the JIVE projects pursued the following objectives and activities:

- ✓ **Deploy 290+ FCB across 16 European cities**
- ✓ **Achieve a price of ≤ €650k and of ≤ €625k per standard bus in JIVE and JIVE 2 respectively / ≤ €1m per articulated bus** – through joint procurement, standardisation, and economies of scale.
- ~ **Demonstrate high reliability of FCB (> 90%)** – operating buses for a minimum of 36 months or 100,000km (JIVE) / 150,000km (JIVE 2)
- ☐ **Demonstrate high reliability of HRS (> 99%)**
- ☐ **Demonstrate routes to low cost (< 9€/kg) renewable hydrogen** – and monitor hydrogen prices developments
- ✓ **Deliver positive environmental impacts -** by operating FCB for extended periods
- ✓ **Provide evidence of the technical and commercial suitability of fuel cell buses for further roll-out**
- ✓ **Stimulate further uptake of FCB** - via a comprehensive, high-impact dissemination campaign

✓ Fully achieved ~ Partially achieved

South Holland (NL)

Groningen (NL)

London (UK)

… and was successfully achieved with a diversity of buses deployed and a wide variety of locations involved in the initiatives

	Location	Country	# of buses	Bus supplier	Size	Decks	Type of H2 supply
JIVE + JIVE 2	**Cologne**	**Germany**	35 + 15	Van Hool + Solaris	12m	Single	Trailer delivery – green H_2
	Wuppertal		10 + 10	Van Hool + Solaris	12m	Single	Waste-to-energy power electrolysis & trailer delivery
JIVE	**Aberdeen**	**UK**	25	Wrightbus	10.9m	Double	Green – on-site electrolysis
	Birmingham		20	Wrightbus	10.9m	Double	Green – on-site electrolysis
	London		20	Wrightbus	10.9m	Double	Trailer delivery – by-product H_2
	Bolzano	**Italy**	12	Solaris	12m	Single	Trailer delivery – methane reforming
	Gelderland	**Netherlands**	10*	Solaris	12m	Single	Trailer delivery
JIVE 2	**Auxerre**	**France**	5	Safra	12m	Single	Green – on-site electrolysis
	Pau		5 + 4	Van Hool	18m 12m	Single	Green – on-site electrolysis
	Toulouse		5	Safra	12m	Single	Green – on-site electrolysis
	Brighton	**UK**	20 + 34	Wrightbus	10.9m	Double & Single	Trailer delivery – liquid H_2
	Emmen	**Netherlands**	10*	Van Hool	12m	Single	Trailer delivery – green H_2
	Groningen		20	Van Hool	12m	Single	Trailer delivery – green H_2
	South Holland		20	Solaris	12m	Single	Trailer delivery – green H_2
	Barcelona	**Spain**	8 + 2	Caetano + Solaris	10.7m 18m	Single	Green – on-site electrolysis
	Jelgava	**Latvia**	1	Caetano	10.7m	Single	Green – on-site electrolysis

*Both sites experienced the loss of 1 bus each due to accidents

What does this table show?

The table provides an overview of the 290+ JIVE and JIVE 2 buses – highlighting deployment locations, fleet sizes, bus suppliers, vehicle specifications (size and deck type), and hydrogen supply details.

One key message that shines through is **diversity**:

- **in locations**: FCB were tested across a wide range of climates and topographies in Europe.
- **in buses**: FCB from 5 European OEMs, using fuel cells from 3 different manufacturers, and of different sizes and configurations were deployed.
- **in learnings**: The variety led to a broad set of operational insights—relevant for stakeholders across regions, climates, and fleet types.

Between 2017 and 2025, the JIVE projects achieved major milestones for zero-emission mobility in public transportation

ZERO EMISSION

Gathering extensive operational data
confirming strong overall bus performance, including excellent fuel efficiency across diverse conditions.

First-of-a-kind deployments
Barcelona becoming the first Spanish city to operate FCB, Pau being the first to deploy articulated FCB, and Brighton & Cologne becoming Europe's first cities with 50+ FCB.

Achieving the JIVE 1 (€650K) and JIVE 2 (€625K) price targets
marking a key step toward cost competitiveness of FCB.

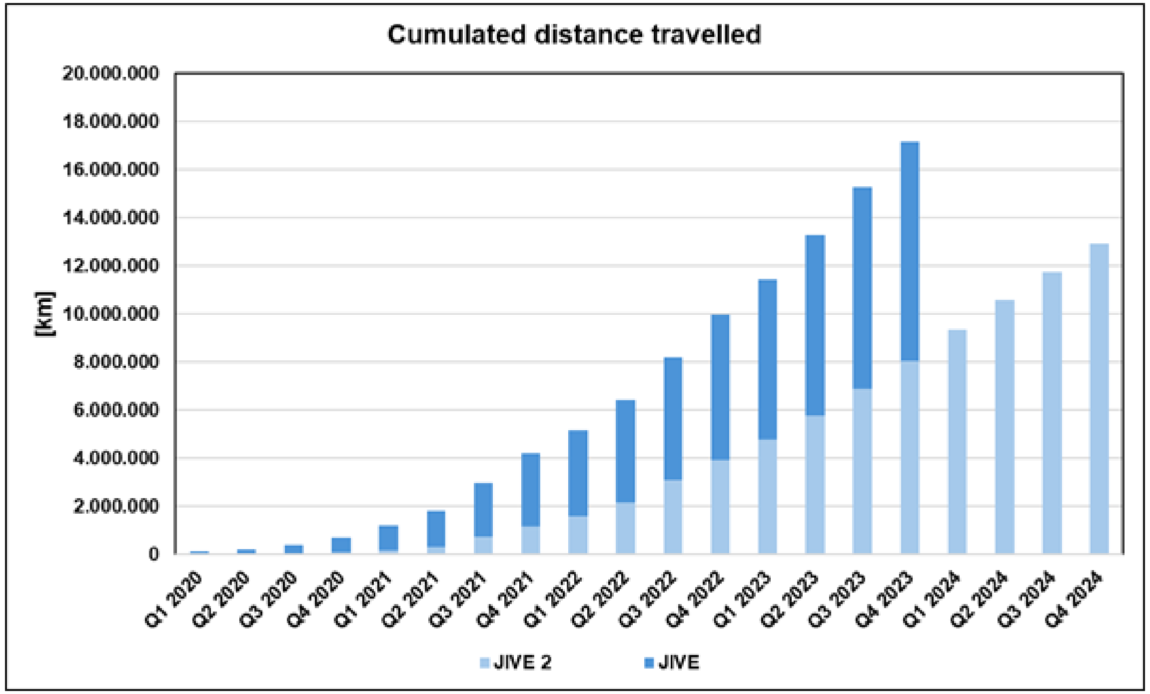
Deploying a wide variety of bus models
including standard, articulated, single-decker, and double-decker buses with an array of configurations and applications.

Four bus roadshows throughout Europe
kick-starting market interest and/or awareness for FCB in Central and Eastern Europe, the Baltics and Northern Europe.

Actively sharing key learnings with the wider sector
through successful ZEB conferences, targeted social media campaigns, JIVE User Group meetings & public presentations.

Throughout the projects' duration, c. 24 million kilometres were driven by the buses under real-world conditions

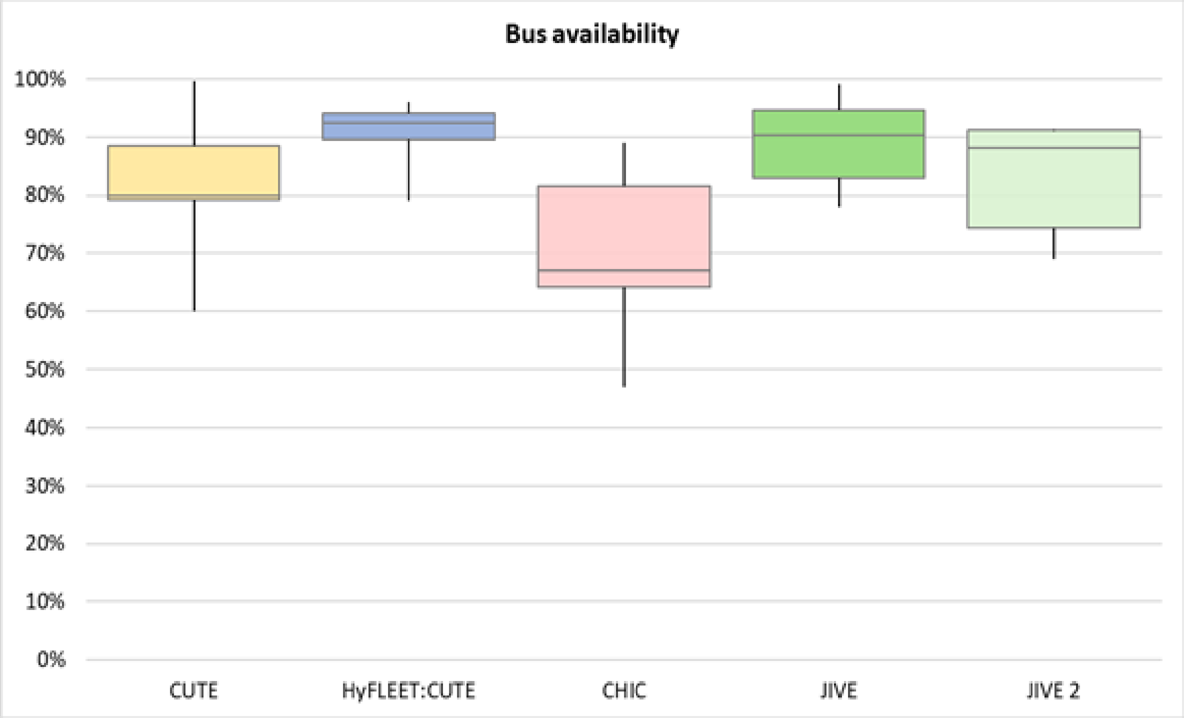
Demonstrating fuel cell bus performance: operating buses for a minimum 44,000 km/year (JIVE) / 150,000 km/bus over 3 years (JIVE 2)



- As the number of buses entering operation grew, the cumulative mileage increased each quarter. By the end of 2023, **10.7 million kilometres had been driven by the JIVE buses** and **13.1 million kilometres had been driven by the JIVE 2 buses** by the end of 2024.
- Almost all sites and all bus brands **reached the targeted distance during at least one month of the project**, with buses on some sites exceeding the target.
- The projects' results show **the buses are capable of performing as expected** in terms of distance travelled.
- **For the sites not achieving the target, various factors enter into play**: difficulties with HRS availability and hydrogen supply, deployment schedules which were planned with shorter distances to be driven, high hydrogen prices, etc.
- As expected, as the number of buses increased, **the amount of hydrogen dispensed also grew to reach 1.6 million kg** by the end of 2024.

The data collected also showed that FCB availability nearly reached target levels

Demonstrate high availability of FCB: > 90%



NB: CUTE and HyFLEET:CUTE project buses had unusually high availability due to intensive, non-standard maintenance

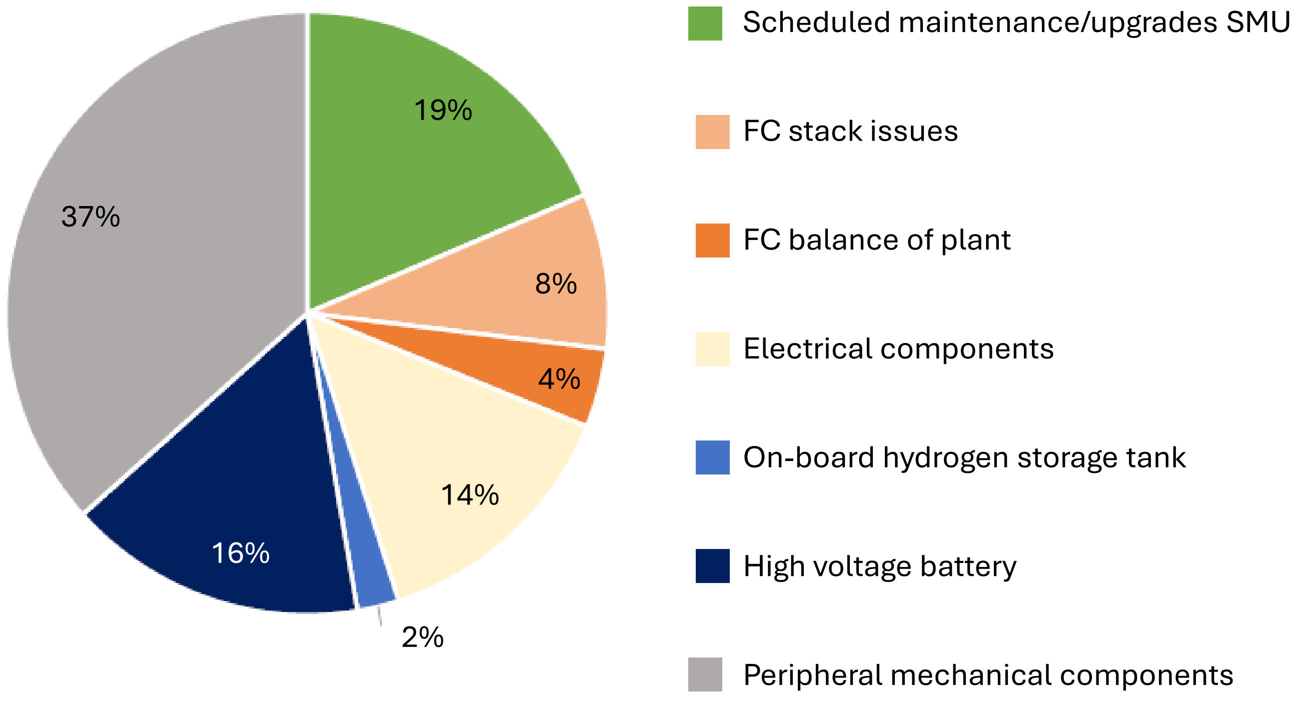
- The projects' average target was **reached by 5 deployment sites**.
- Looking at the median of the monthly availability, **11 sites (out of 18*) met the availability** target of >90%, with an average availability of 84%.**
- Factors that negatively impacted the availability levels include:
  - Long waiting times for spare parts (hydrogen or non-hydrogen-related components)
  - Extensive and lengthy repairs (for example due to lack of locally-based technicians).
- Compared to previous projects, no pronounced teething periods were observed.
- Despite the targets not being reached, sites have mostly expressed satisfaction with the levels achieved.

* Pau, Wuppertal and Cologne are counted twice because they have two different bus models. Jelgava is not in this data.
** Availability is defined as the general round-the-clock (24/7) readiness for services. Downtime hours are derived from the time stamps of trans-fer to workshop and back to operation

Data from JIVE 2 partners showed that FCB downtimes were not typically caused by hydrogen-specific components.

Demonstrate high availability of FCB: > 90%

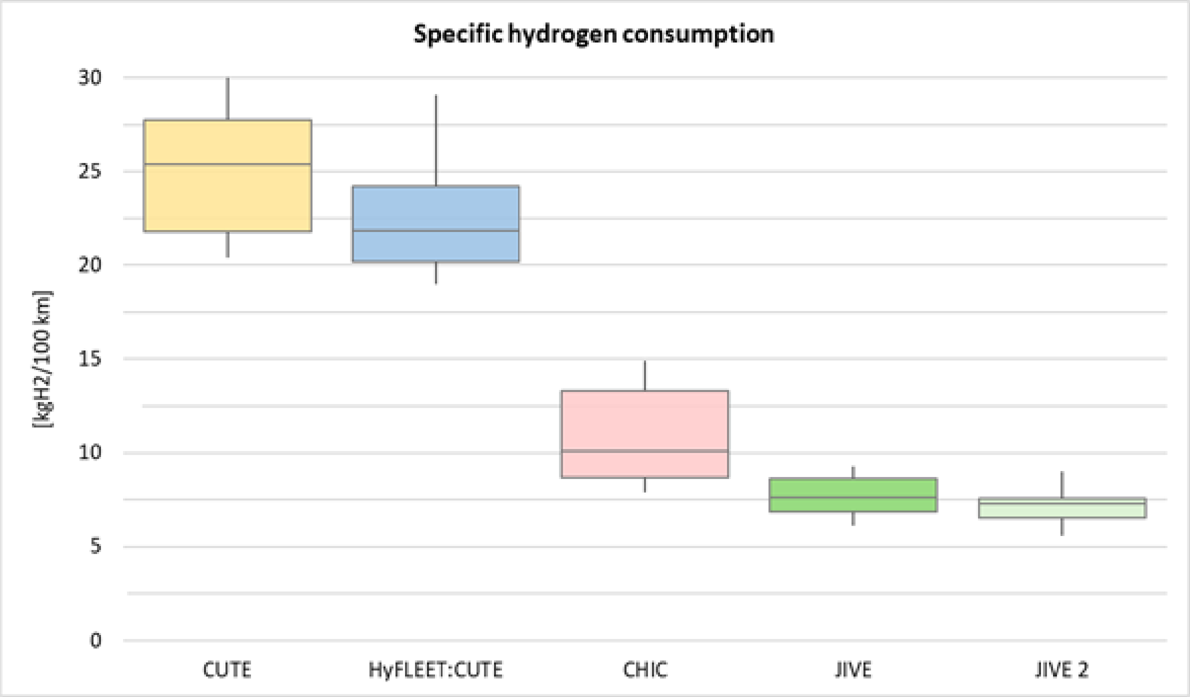
Reasons for downtime (JIVE 2 FCB)



- **Downtime was typically not caused by the fuel cell drivetrain** (e.g. – high voltage battery, mechanical issues, HVAC, etc.)
- Longer downtimes have also been observed to be caused by **external factors**, e.g., the availability of the station or hydrogen
- Failures related to peripheral mechanical components were the most frequent cause for downtime, followed by scheduled maintenance and upgrades, and issues regarding the high voltage battery.

In terms of fuel consumption, buses outperformed targets with excellent efficiency

Provide evidence of the technical and commercial suitability of fuel cell buses for further roll-out



2001 – 2005	2006 – 2009	2010 – 2016	2017 – 2025
27 FCB	47 FCB	54 FCB	290+ FCB

The following targets were set for fuel consumption in the JIVE and JIVE 2 projects:

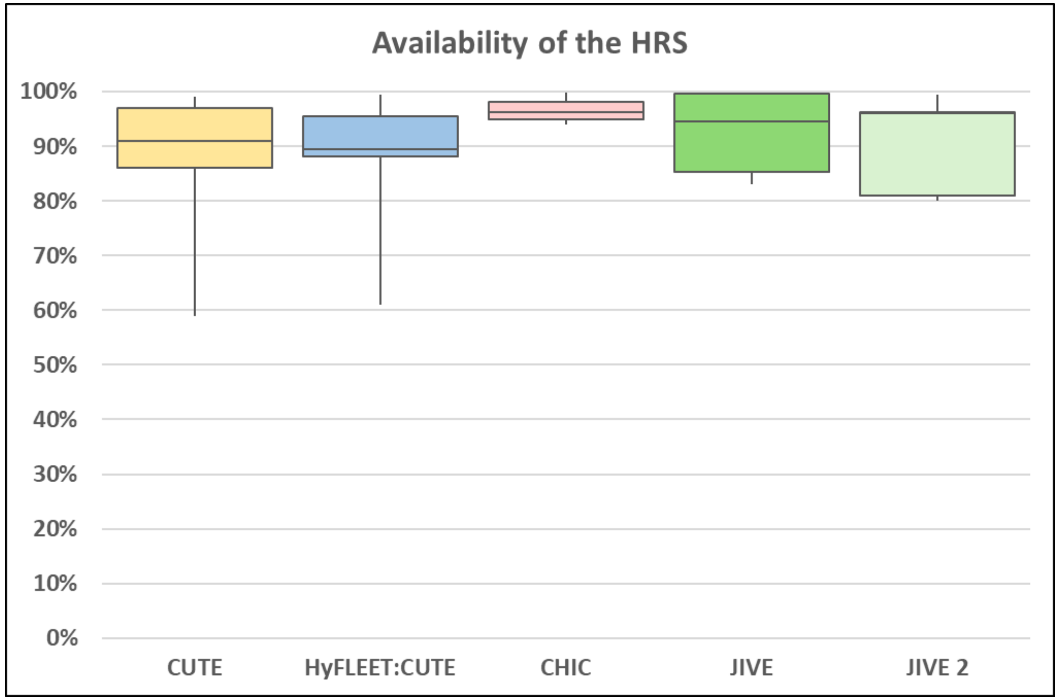
- **< 9kg/100km** for standard buses
- **< 14kg/100km** for articulated buses

From data collected on fuel consumption, three main conclusions can be drawn:

- **Excellent fuel efficiency**: During the project, hydrogen consumption ranged between 5.5–9.1 kg/100 km for 12 m and double-decker buses, and ~9 kg/100 km for 18 m articulated buses.
- **Performance exceeding expectations**: Most buses outperformed the original fuel efficiency targets.
- **Marked improvements over time**: Data shows a significant reduction in fuel consumption compared to previous projects and throughout the project duration, reflecting progress in technology and operations.

HRS availability, however, remained a critical performance hurdle across the projects

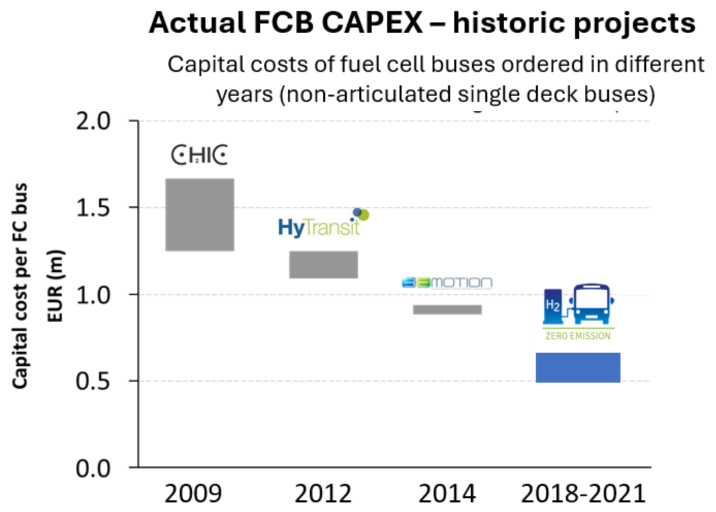
❑ **Demonstrate high reliability of HRS (98% with aspiration to achieve >99%)**

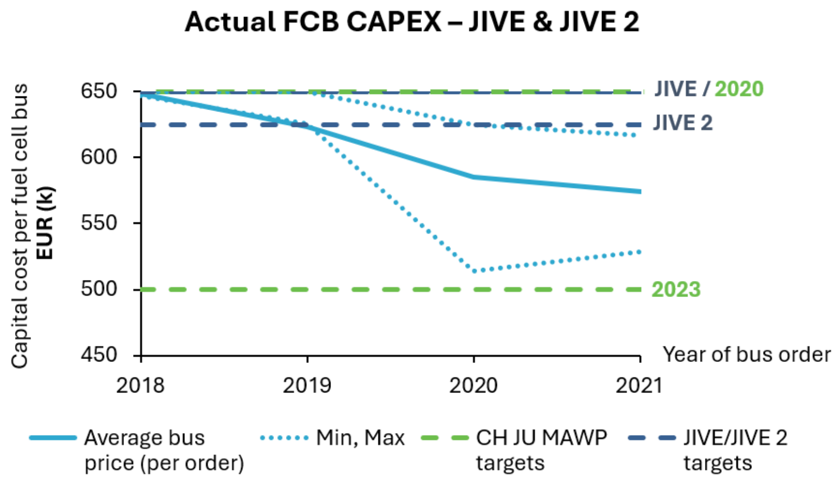


- The target was met by 3 sites, and **average availability ranged from 80% to 99.6%**.
- Despite all sites having had months during which >99% availability was achieved, this is **not sufficient to ensure a reliable system for bus operators** – even a HRS with 99% availability means that during at least 3.5 days/year there is no hydrogen available, resulting in no FCB operating.
- Reasons for downtime experienced by HRS in the projects include:
  - **External factors**: lack of fuel due to failures in the supply chain for hydrogen delivery or outages at the hydrogen production units.
  - **Internal factors**: issues with hydrogen storage, dispensing equipment, hydrogen compressors, or alarm and safety devices.
  - These issues were not only experienced during the teething period but also **continued throughout the project**.

During the JIVE initiatives, a downward trend in fuel cell bus prices was observed compared to past projects

Achieve a price of ≤ €650k/€625k per standard bus (JIVE and JIVE 2 respectively) / ≤ €1m per articulated bus





- **Prices have significantly decreased** compared to preceding funded FCB projects, driven by the increased scale of deployments under JIVE and JIVE 2.
- Both JIVE and JIVE 2 **met their price targets**, which were aligned with the Clean Hydrogen Partnerships Multi Annual Work Plan targets for 2020.
- Lowest prices are typically achieved for orders of more than 10 buses, although final costs vary based on vehicle specifications, warranty extensions, etc.

Despite this progress:

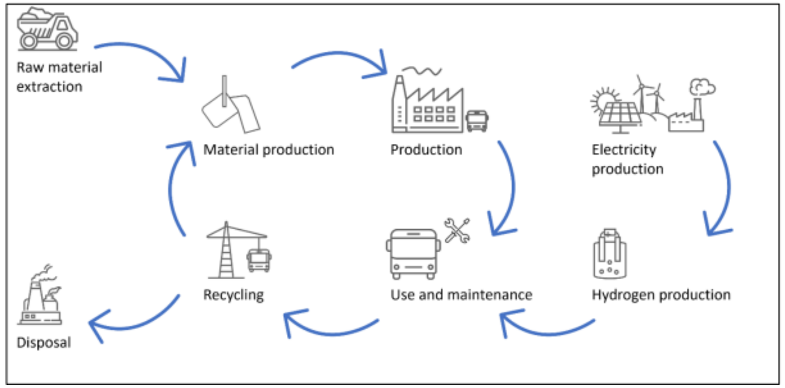
Further cost reductions are still essential to achieve commercially viable, subsidy-free offers.

These reductions must be achieved without compromising on quality or the high reliability standards expected of FCB.

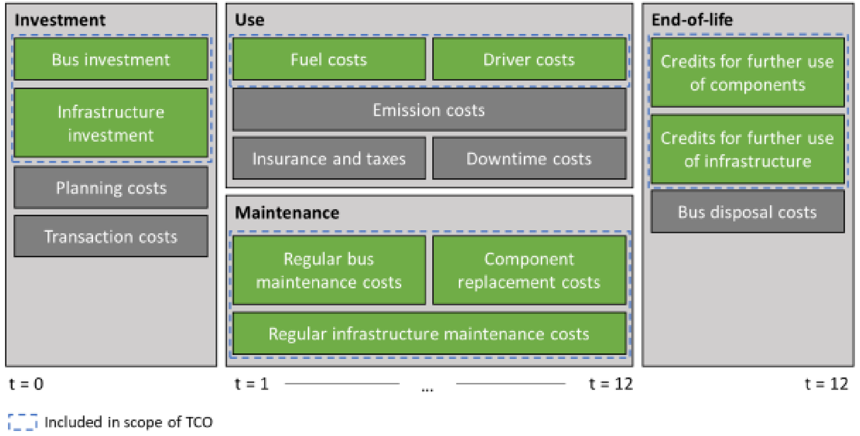
A TCO and LCA study was carried out, comparing FCB and BEB

Demonstrate the economic and environmental impact of FCB

Stages considered in LCA



Costs included in scope of TCO



- Led by Sphera, a Total Cost of Ownership (TCO) and Lifecycle Analysis (LCA) study (2023) was carried out to evaluate the environmental and economic performance of FCB against alternative solutions. As diesel buses are not viable in a net zero future, the **FCB and BEB comparison is crucial**.
- FCB and BEB were analysed and compared **using real-world data from the JIVE projects**.
- **Two JIVE and JIVE 2 sites were selected for analysis**, where both FCB and BEB operate.

Overall, BEB show advantages as a 1-to-1 replacement, but:

Results are highly dependent on specific local conditions, and FCB can show advantages depending on operator requirements

Relative advantage of BEB is smaller if additional vehicles are required to deliver full service, and if grid capacity constraints limit the ability to charge the fleet efficiently.

Further insights from the study are highlighted in the following three slides.

The study was based on real-world data collected from two project sites

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The two sites from which the data was collected operate different vehicle and route types, as reflected in the table below. Double deck buses serving dense urban areas operated from Site 1, while single deck buses served less dense, longer distance routes from Site 2.

These differences demonstrably affect both the economic and environmental performance of both BEB and FCB, highlighting the influence of local factors on vehicle suitability.

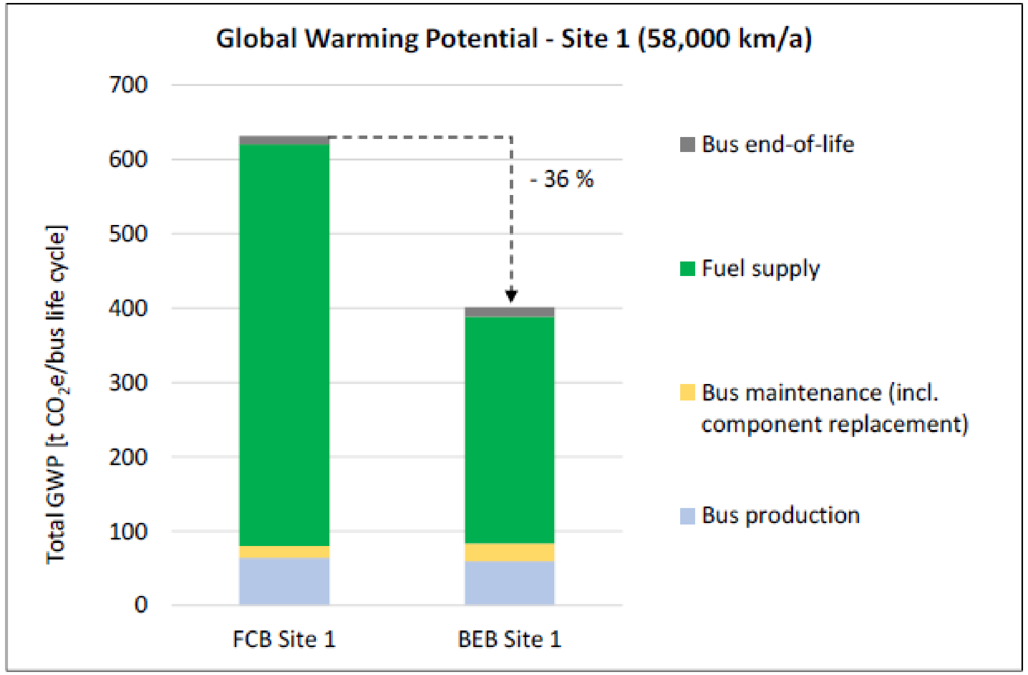
Breakdown of key parameters across the two depot sites

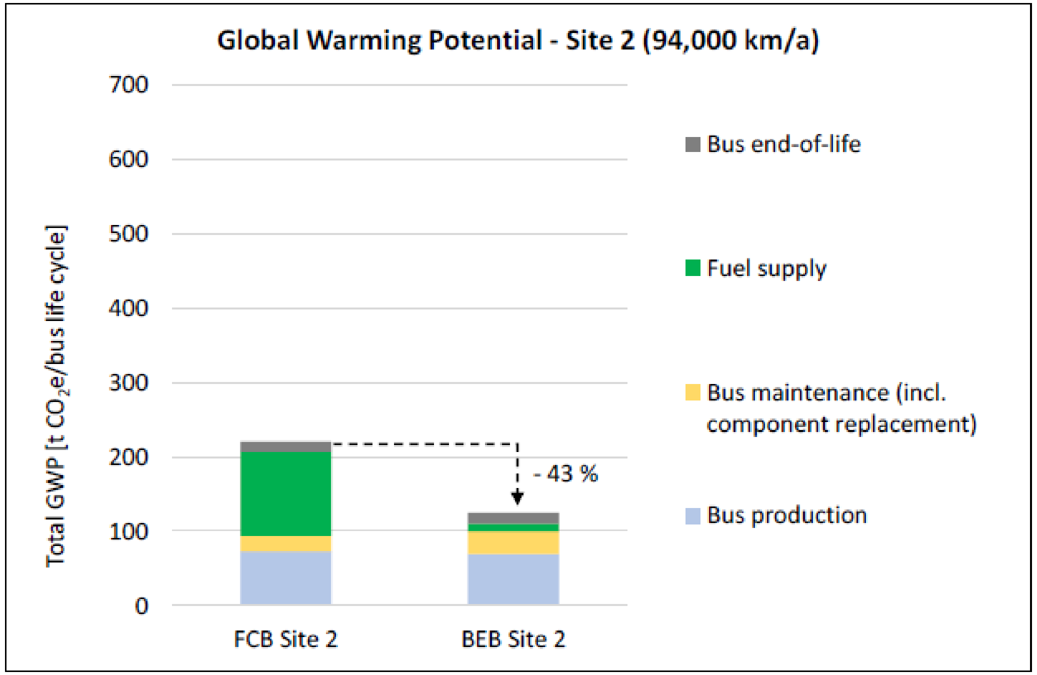
	Site 1 – Annual Distance Driven: **58,000** km		Site 2 – Annual Distance Driven: **94,000** km	
	FCB	**BEB**	**FCB**	**BEB**
Bus Characteristics	Double-deck 12,050kg 85 kW fuel cell 27.4 kWh LTO battery	Double-deck 11,180kg Depot Charging 300 kWh LFP battery	Solo 13,755 kg 83 kW fuel cell 24 kWh LTO battery	Solo 12,850 kg Depot charging 362 kWh LFP battery
Bus Operation	6.4 kg H_2 /100 km Hydrogen via Chlor-Alkali electrolysis with grid mix	133 kWh/100 km Electricity: grid mix	6.7 kg H_2 /100 km Hydrogen via electrolysis with electricity from wind	110 kWh/100 km Electricity: 100% wind
Economic Parameters	Bus price: 664,000 € Hydrogen: 6.8 €/kg H_2	Bus price: 531,675 € Electricity: 0.18 €/kWh	Bus price: 625,000 € Hydrogen: 7.0 €/kg H_2	Bus price: 450,000 € Electricity: 0.21 €/kWh

Further details can be found in the report (Link)

The LCA demonstrated the Global Warming Potential for FCB remains higher than for BEB due to fuel supply emissions

Demonstrate the environmental impact of FCB is comparable with BEB





- BEB from Site 1 have on average a **36% lower Global Warming Potential (GWP) than FCB**.
- This is **driven primarily by fuel supply emissions**, as conversion losses in hydrogen production increase electrical energy consumption.
- Despite higher mileage than Site 1 vehicles, both vehicle types at Site 2 have greatly reduced emissions **due to wind energy supply**, instead of grid power (Site 1).
- FCB at Site 2 have a lower carbon footprint than Site 1 BEB, highlighting the **impact the energy source has on GWP**.

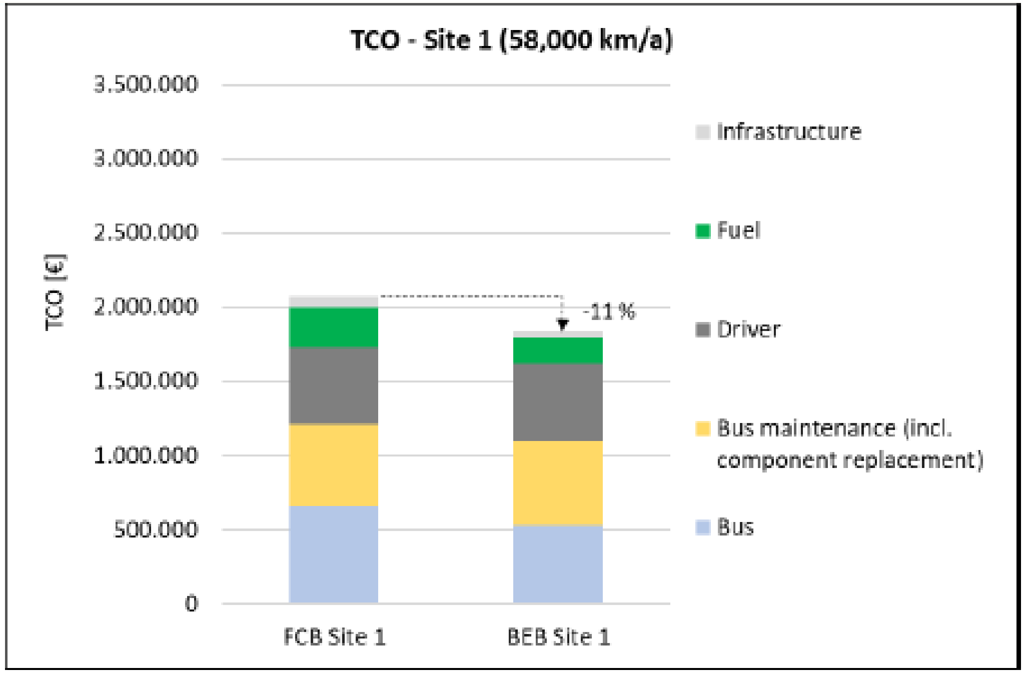
Further details can be found in the report (Link)

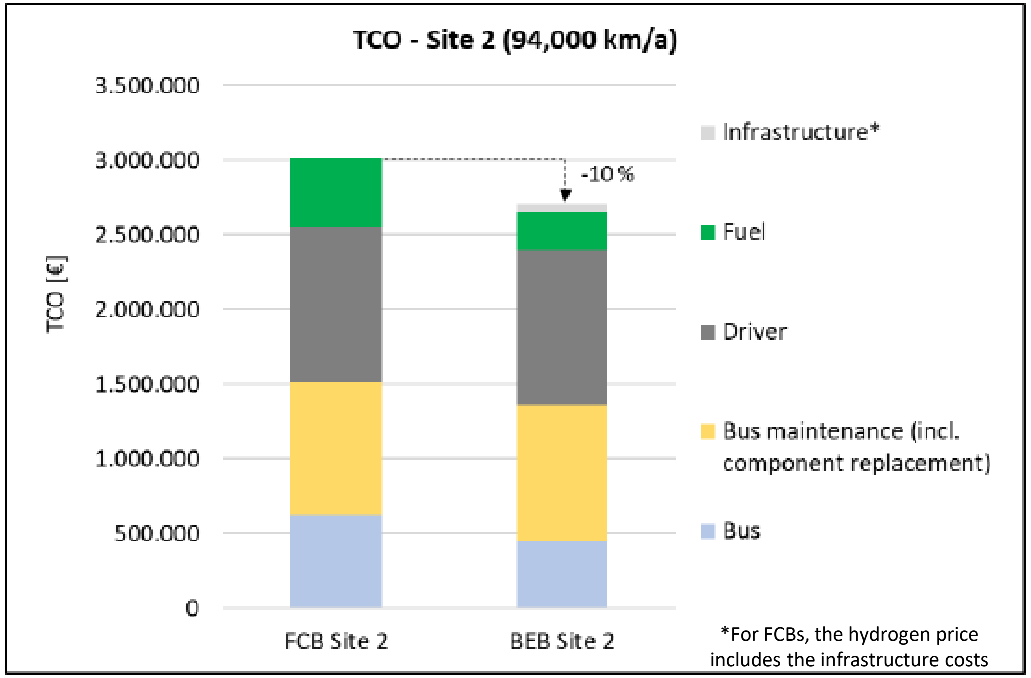
The TCO analysis demonstrated that higher costs associated with FCB are linked to bus prices, maintenance and fuel costs

ZERO EMISSION

Overview | Takeaways | MEHRLIN | JIVEs | Challenges | Future

Demonstrate the economic cost of FCB is comparable with BEB





- TCO for BEB are 11% lower than FCB at Site 1, while 10% lower at Site 2.
- In this analysis, **BEB have an advantage in fuel and infrastructure costs**; however, these costs categories represent less than 20% of the TCO in every case.
- **The main cost drivers are bus price, bus maintenance, and driver costs**. BEB vehicle costs are 24% lower at Site 1 and 28% lower at Site 2, reflecting the earlier stage of commercialization of FCBs in these projects.
- Maintenance and driver costs become increasingly important for longer distance routes.
- For operators with constraints that prevent the deployment of BEBs (e.g. highly demanding routes, grid constraints for depot charging), FCBs can provide a more operationally flexible alternative with a relatively small impact on TCO

Further details can be found in the report (Link)

Content

Throughout the projects, six key challenges emerged

JIVE, JIVE 2 and MEHRLIN represent the **first large-scale FCB and HRS deployment projects**, and as such, have faced challenges in various project stages. Some of the challenges were framed within the project duration while others will continue to have an impact on the project partners' activities post-project.

Solutions and mitigation measures have been implemented in many cases, and findings have been documented in the **Best Practice report** to transfer these learnings to the wider sector.

COVID

The pandemic significantly disrupted procurement, manufacturing, delivery, and the execution of public transport operations.

Hydrogen sector & bankruptcies

The hydrogen mobility sector experienced market turbulence over the course of the project, including bankruptcies of key suppliers (e.g., bus OEMs).

Data availability and delivery

Delays and gaps in delivered data limited the scope and speed of analysis.

Hydrogen prices

Elevated hydrogen prices, partly driven by the electricity price crisis in 2022 and 2023, had a significant impact on operations at several sites.

Fuel cell degradation

Some sites experienced lower performance when FCB were operating outside of their design specifications, highlighting the need for monitoring, maintenance strategies, and collaboration with OEMs to improve long-term durability.

HRS and FCB availability

Lack of station redundancy led to HRS operations being highly vulnerable to technical issues and in turn to downtime. In terms of buses, long waiting times for spare parts and maintenance services impacted FCB availability.

HRS dependability was a critical issue in the projects, with three improvement recommendations highlighted in a dedicated study.

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What goes wrong?	What leads to these failures?	What stops it being fixed?
HRS equipment reliability	• Station design may be overcomplicated and does not meet actual requirements • The equipment is not suitable for how HRS currently operates • Integration or installation expertise is limited	• Station design approach is flawed • Equipment is unavailable
Maintenance arrangement	• There are not enough trained maintenance personnel • Insufficient local spare parts storage • Lack of training or knowledge sharing within or between organisations	• Cost of resolution is higher than overall benefit • Other hydrogen supply clients take priority over HRS
Hydrogen supply and delivery	• Single hydrogen source is unavailable or used to satisfy competing demands • Non-standardised delivery equipment makes delivery impossible	• Training for HRS designers and developers is not mandated • No effective way to share learning

What can be done to improve HRS dependability?

- Align incentives to ensure HRS operators' and OEMs' revenue is linked to ongoing performance, station uptime and throughput.
- Ensure contracting & tendering is fit for purpose, and that station design specifications reflect the market status and capabilities.
- Improve knowledge management & sharing, to ensure learnings from prior HRS projects are incorporated in station design and operation.

Link to full deliverable in the Annex of this presentation

Hydrogen prices have experienced a significant increase during the project duration, and currently sit above the targeted price

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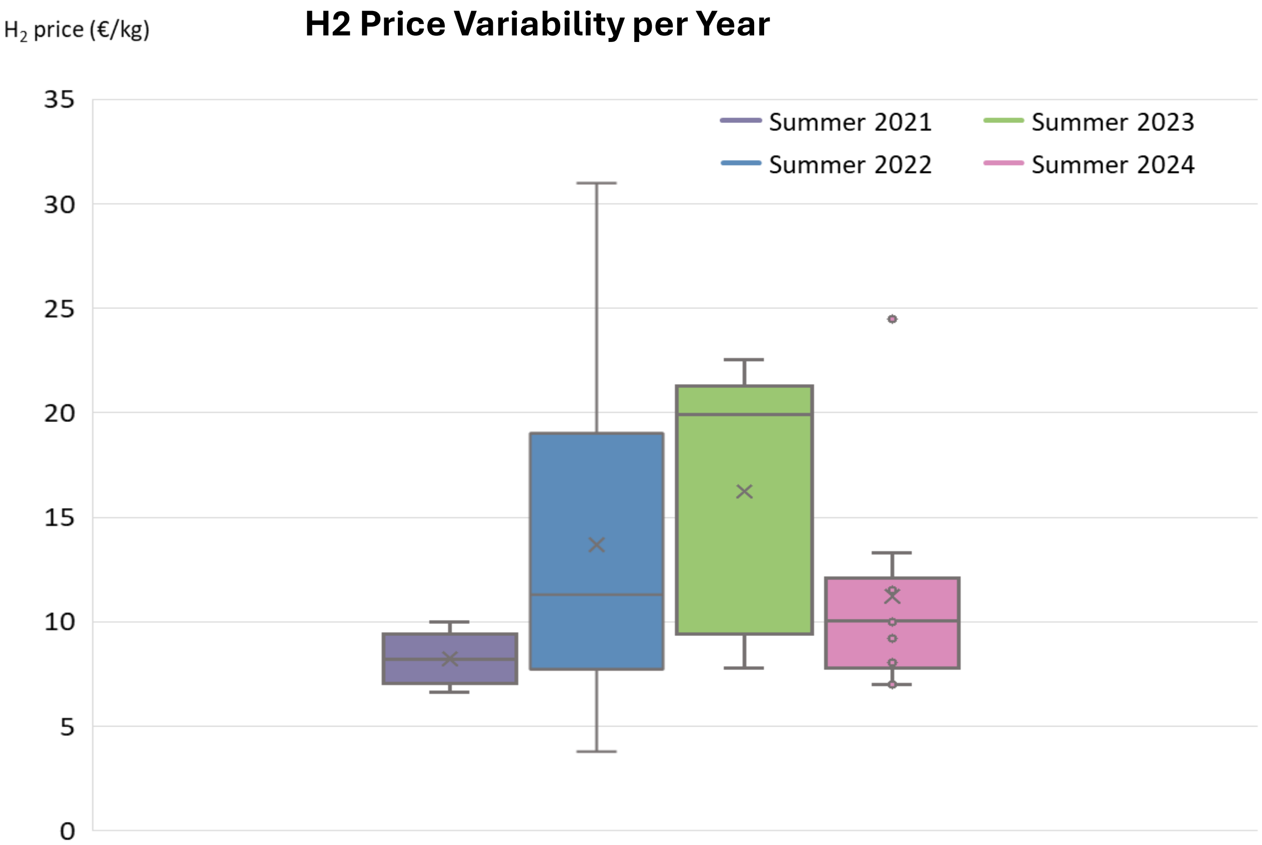
❑ Demonstrate routes to low-cost hydrogen (< 9€/kg)



NB: Not all sites are represented in the data.

While average prices have fluctuated, **price variability significantly improved in 2024 compared to 2022**.

- The volatility in electricity prices and hence hydrogen prices was driven by a series of factors, primarily **the energy crisis and hydrogen supply challenges**.
- The subsequent narrowing of the price range, excluding some outliers, indicates **a return to more stable and consistent pricing** across sites.
- The high hydrogen prices have had **important impacts on the project** as some sites had to reduce the number of buses in operation during the price peaks.

The project observed differences across the sites and the regions involved in the project.

- Partners that negotiated **fixed long-term contracts** (for the price of electricity or hydrogen) at the start of the project, were less impacted.

Mitigation measures were investigated and implemented by project partners such as reviewing the electrolyser functioning time to match the off-peak periods.

The **high hydrogen prices remain a key obstacle** to further deployments for many project partners and interested stakeholders.

Content

Some MEHRLIN, JIVE and JIVE 2 partners have committed to a FCB future, investing in buses and infrastructure beyond the projects

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With the delivery of **31 FCB in 2024**,
RVK's total **fleet now consists of 130 FCB**,
50 of which were procured **through the JIVE projects**.

- Regionalverkehr Köln (PTO in Cologne) now operates the **largest fleet** of FCB in Europe.
- The fleet features buses from several OEMs, i.e., **Van Hool, Solaris, and Wrightbus.**
- Three HRS were constructed/upgraded during the MEHRLIN and JIVE projects, with a **fourth station beginning operations in October 2025.**

With the delivery of **34 FCB in 2025**,
Metrobus' total **fleet now consists of 54 FCB**,
all of which were procured **through the JIVE 2 project**.

- Metrobus (PTO in Brighton) now operates the **largest fleet of FCB in the UK**.
- The fleet features both **single- and double-decker** buses, all of which are from Wrightbus.
- The **UK's first liquid HRS** was built to refuel JIVE 2 buses, with operations commencing in November 2024.

With the delivery of **2 new articulated FCB in 2024**,
TMB's total **fleet now consists of 46 FCB**,
10 of which were procured **through the JIVE 2 project**.

- Transports Metropolitans de Barcelona (PTO in Barcelona) now operates the **largest fleet of FCB in Spain**.
- The fleet includes both **12-meter (standard) and 18-meter (articulated) buses** from Caetano and Solaris.
- TMB plans to **further expand its FCB fleet**, alongside a strategic **expansion of HRS** in the coming years.

Four fuel cell bus roadshows were conducted in 34 cities of 15 Central, Eastern and Northern European countries

1st roadshow *(Nov 2022 – Jan 2023)*
- Slovenia
- Croatia
- Czechia
- Slovakia
- Hungary

The bus travelled a **total distance of 1,641 km**
Key learnings and impacts (here)

2nd roadshow *(Aug – Oct 2023)*
- Poland
- Lithuania
- Latvia
- Estonia

The bus travelled a **total distance of 1,450 km**
Key learnings and impacts (here)

3rd roadshow *(May – Jun 2024)*
- Romania
- Greece
- Bosnia-Herzegovina
- Bulgaria

The bus travelled a **total distance of 2,814 km**
Key learnings and impacts (here)

4th roadshow *(April – Jun 2025)*
- Sweden
- Finland

The bus travelled a total distance of **over 1,900 km**
Key learnings and impacts (here)

100% of the cities that trialled the technology announced **formal interest in deploying FCBs**

Contribution to creation or strengthening of **collaboration between stakeholders**




The roadshows have had a major impact with over 79% of all identified cities having expressed formal interest in deploying FCB

Across the three roadshows*, a total of **36 cities** participated. An analysis was conducted **on 21 additional cities**, which were identified by national coordinators as potential future demand centers in **roadshows** countries.

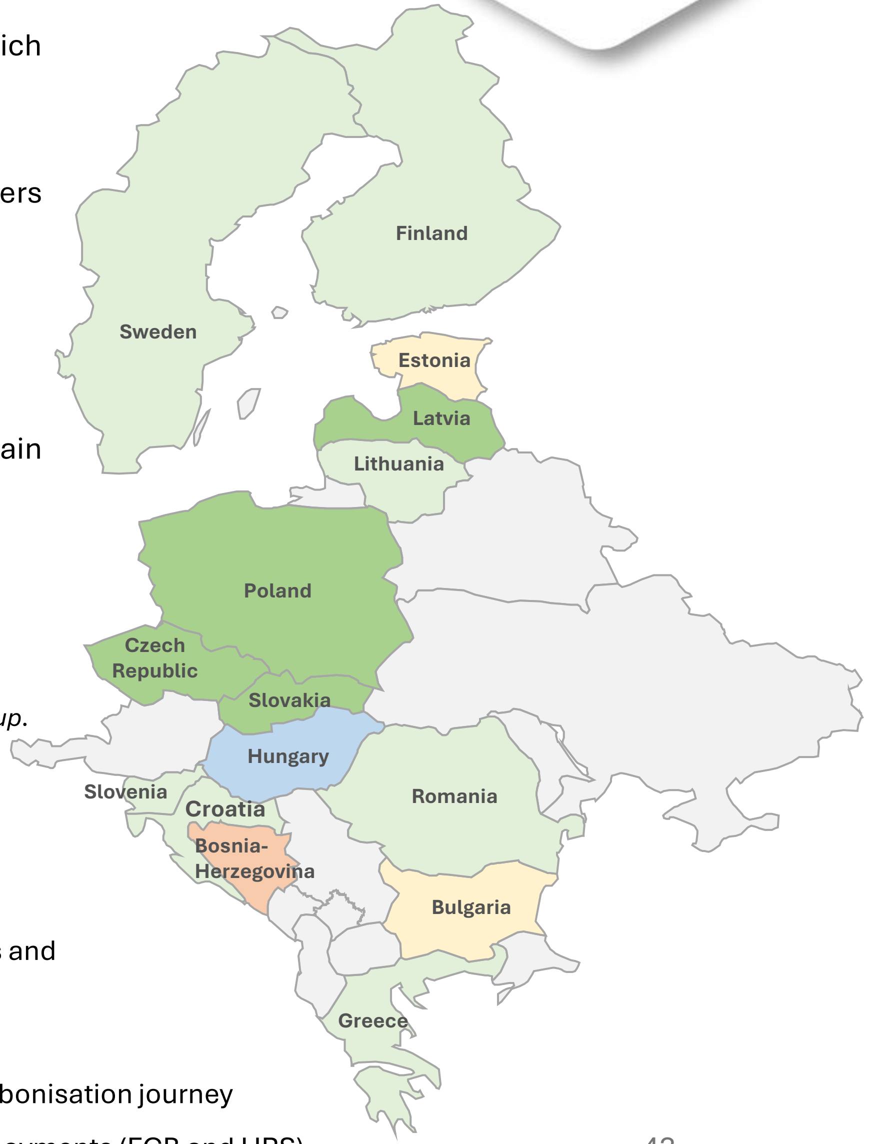
Out of these **57 cities**, information was collected from **72% of them**.

- Among those, **80%** are either still interested in hydrogen technology or have already deployed FCB. The main drivers for choosing this solution include:
  - Key **technological advantages** of the hydrogen technology
  - **Positive results** from pilot projects
  - Availability of **national and EU funding**
- Meanwhile, **20%** of those cities have not deployed FCB and do not plan any deployments in the near future. The main reasons identified for showing lower interest are:
  - Preference to **BEB solutions**, with **existing infrastructures** already in place
  - **Economic concerns** due to limited refueling infrastructure and overall technology maturity
  - Strategic focus on **first developing green hydrogen production** before any transport deployment

**The fourth roadshow (Sweden & Finland) concluded in June 2025 and therefore the cities that have participated are not included in this wrap-up.*
NB: Analysis based on public announcements and news articles.

Legend:

- Countries where both participating and non-participating cities have already deployed fuel cell buses and hydrogen infrastructures since the roadshow
- Countries where both participating and non-participating cities have announced upcoming deployments of fuel cell buses and hydrogen infrastructures
- Countries with hydrogen production site construction projects only
- Countries that have not shown further interest in hydrogen technology, opting instead for electric solutions for their decarbonisation journey
- Countries that continue to show strong interest in the technology through parallel actions but have no planned future deployments (FCB and HRS)



Latvia and Hungary are two of the success stories resulting from the Central and Eastern European roadshows

Latvia

During the 2nd roadshow, the city of Jelgava expressed keen interest in hydrogen technology. Following a request, the city of Jelgava joined the JIVE2 consortium, with **the objective of acquiring, deploying and operating one fuel cell bus for a one-year period.**
The bus was used for the Nordic Roadshow, covering a total distance of over 1,900 km in Sweden and Finland.

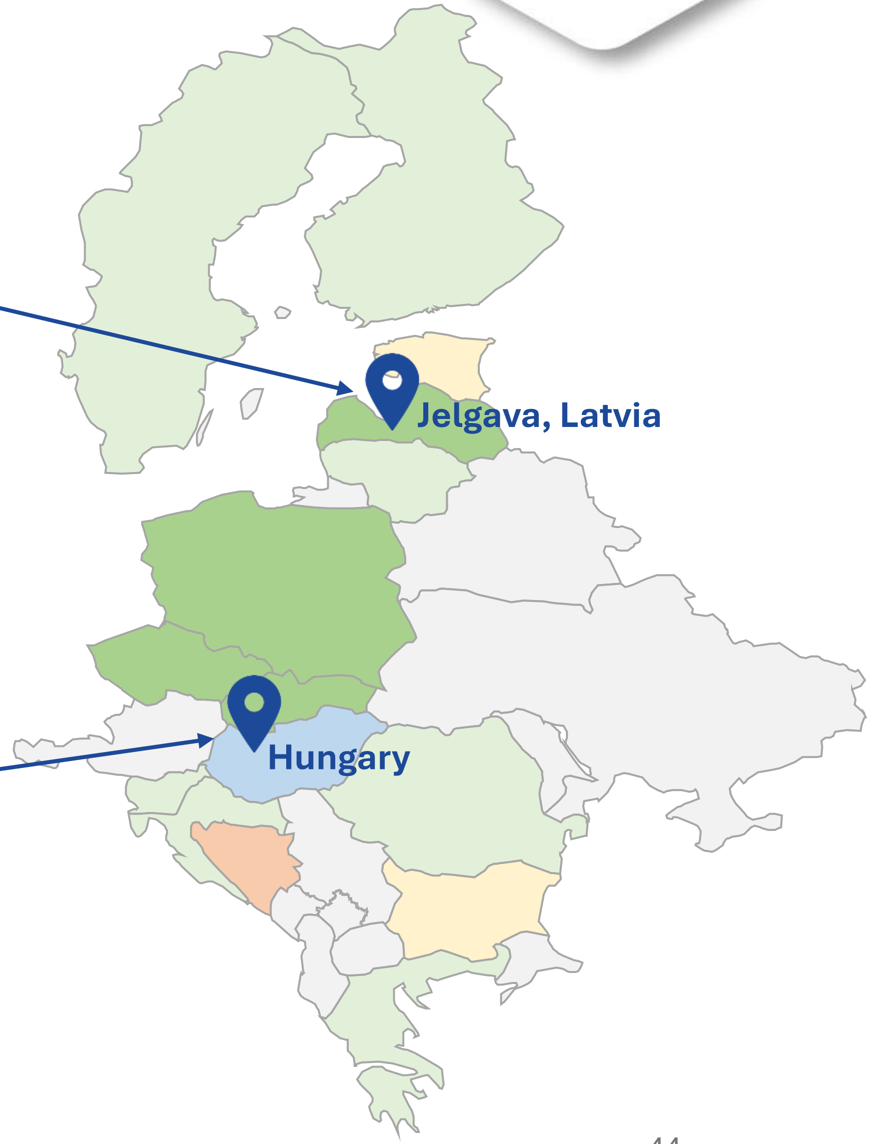
Hungary

Following the 1st roadshow, Hungary launched in 2024, a national pilot to test FCB as part of its hydrogen strategy. This included:

1. **Organisation of its own national roadshow across six regional cities** to showcase benefits of FCB across the country.
2. **A long-term FCB test in Budapest**

Both projects were supported by **fixed and mobile HRS**.
The tests were conducted **using two different FCB**, a Solaris Urbino and a Toyota Caetano FCB.

In total, the buses covered over **60,000 km**, averaging **214 km/day,** consumed **4,500+ kg of hydrogen**, and helped avoid **35 tonnes of CO_2 emissions.**



Looking ahead: the MEHRLIN and JIVE projects' ingredients for a successful fuel cell bus market

Through MEHRLIN, JIVE, and JIVE 2, the consortium has gained valuable insights, knowledge, and hands-on experience in deploying FCB. As these projects come to an end, four key elements have emerged as essential to advancing FCB into a successful commercial phase:

Scale for cost reduction

Strong and growing demand for fuel cell buses is essential to unlock economies of scale and reduce production and operating costs. This can also lower hydrogen prices through bulk purchasing, efficient supply chains, and access to affordable low-carbon electricity for cost-effective production. Hydrogen Valleys and holistic ecosystems play a key role in this.

Continuing to strengthen safety systems

While the safety systems put in place for the deployment of fuel cell buses and hydrogen refuelling stations proved to be effective throughout the projects, mandatory trainings and inclusion of other stakeholders (incl. emergency response teams) must be ensured to safeguard public safety and maintain operational reliability.

Maintenance, spare parts and dependability

Transport operators' willingness to adopt and invest in FCB fleets is crucial for demonstrating viability and accelerating the shift to cleaner public transport. To support this, reliable maintenance for stations and buses, as well as secure spare parts supply chain, must be ensured. In addition, buses and especially hydrogen refuelling stations must reach higher levels of dependability.

Identifying FCB advantage

BEB demonstrated TCO and life cycle emissions relative to FCBs under certain conditions, making them the preferred option for many European operators and authorities. It is therefore important to identify use cases where FCB can add value (or outperform) BEB for specific use cases. Two reports exploring where FCBs have a competitive advantage in Europe were developed within the project – linked here and here.

Thank you for your attention

Project coordination:

ERM

Project dissemination:

Hydrogen Europe

The **JIVE and JIVE2 projects** have received funding from the Clean Hydrogen Partnership under Grant Agreement No 735582 and 779563.

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The **MEHRLIN project** is co-financed by the **European Union's Connecting Europe Facility.**

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Content

List of other deliverables from the JIVE and JIVE 2 projects

All the deliverables can be found on the projects' website or LinkedIn page

- Best Practice Report (June 2024): JIVE/JIVE 2 Final Best Practice Report D3.26 / D3.29
- The potential for H2 buses in Europe (April 2025): The potential for hydrogen buses in Europe: Analysis of alternatives - April 2025
- Guide to options for hard-to-decarbonise bus routes (April 2025): D4.27 Guide to options for hard-to-decarbonise bus routes
- Fuel Cell Bus Implementation Plan (March 2025): D4.4 – Fuel Cell Bus Implementation Plan – Report on remaining barriers and proposed solutions | Fuel Cell Electric Buses
- Key learnings and impacts from the 1st JIVE 2 CEE bus roadshow: D4.13 Lessons learnt from the 1st JIVE 2 CEE bus roadshow | Fuel Cell Electric Buses
- Key learnings and impacts from the 2nd JIVE CEE bus roadshow: D4.21 2nd Roadshow Lessons Learned | Fuel Cell Electric Buses
- Key learnings and impacts from the 3rd JIVE CEE bus roadshow: D4.12 roadshow learnings | Fuel Cell Electric Buses
- Fuel cell bus rollout in Sweden (April 2024): D4.8 - Fuel cell bus rollout in Sweden. Developing pathways to post-JIVE deployment in Scandinavia | Fuel Cell Electric Buses
- Fuel cell bus deployment in the UK (June 2024): Fuel cell bus deployment in the UK – lessons from JIVE and next steps | Fuel Cell Electric Buses
- Environmental Impacts and External Cost Benefits of FCBs (May 2023): Environmental Impacts and External Cost Benefits of FCBs – Comparison of FCBs with BEBs | Fuel Cell Electric Buses
- Best Practice Guide for FCB Maintenance Workshops (June 2024): FCB_Maintenance_Workshop_Guidelines__JIVE_D3-34_JIVE_2_D3-5| Fuel Cell Electric Buses
- Operators' guide to fuel cell bus deployment (June 2024): D2.2 Operators' guide to fuel cell bus deployment | Fuel Cell Electric Buses
- Report on the lessons learned from joint procurement (Feb. 2024): D1.1 - Report on the lessons learned from joint procurement | Fuel Cell Electric Buses
- Analysis of economic data - MEHRLIN (2023): D3.1 - Analysis of economic data Public report | Fuel Cell Electric Buses
- Interim analysis of the impact on urban bus service operations and operator attitudes: D3.20 – Interim analysis of the impact on urban bus service operations and operator attitudes | Fuel Cell Electric Buses
- Environmental impacts and external costs/benefits of FCBs compared to BEBs: Environmental Impacts and External Cost Benefits of FCBs – Comparison of FCBs with BEBs | Fuel Cell Electric Buses
- HRS Dependability: Learnings from the Industry (2025): HRS Dependability: Learnings from the Industry