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Zero emission buses in Europe: status and outlook

Introduction

The official launch of the fleet of hydrogen fuel cell buses on Metrobus' Fastway service is a major milestone in the *JIVE 2* project. Whereas the other UK projects in the JIVE programme are led by public sector organisations, this deployment was led by a private sector bus operator. This is also the final project of the 16 within the total suite of JIVE projects across Europe to begin operating buses; and the vehicles will serve a route which offers a 24-hour per day service. There have been many developments in the zero-emission bus (ZEB) sector since JIVE began in 2017. This paper reflects on the status of the sector and considers some of the challenges and opportunities associated with the transition to clean buses.

Joint **I**nitiative for hydrogen **V**ehicles in **E**urope is the name given to the EU's flagship fuel cell bus demonstration programme. Together the projects JIVE and JIVE 2 will lead to the deployment of c.300 fuel cell buses in 16 sites across six countries.

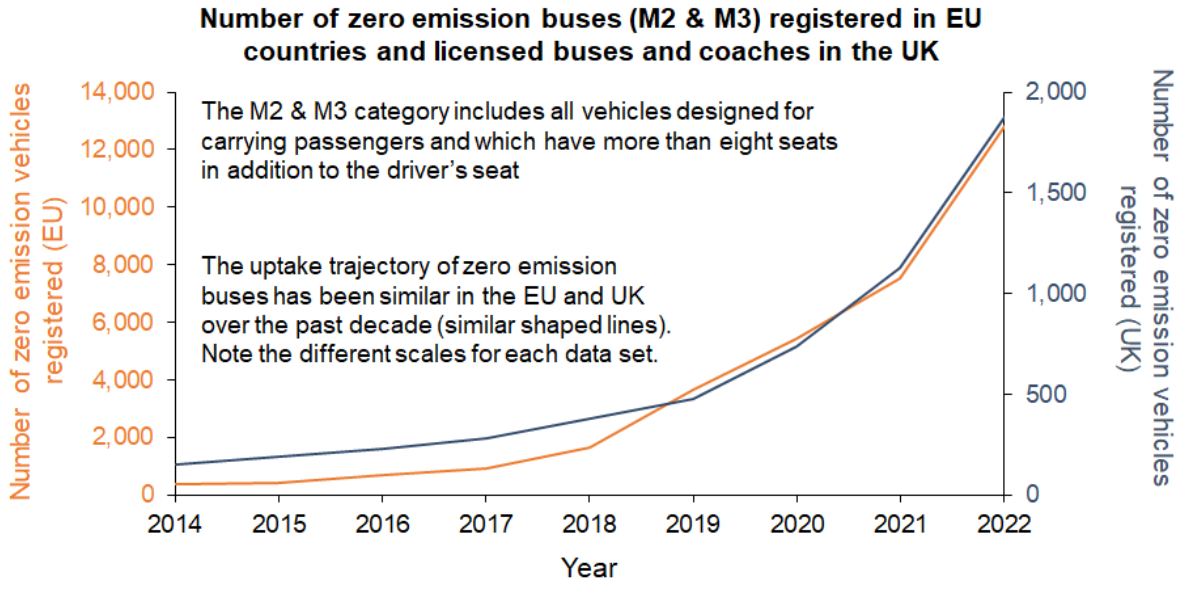
Context

The JIVE programme was conceived in the mid-2010s, building on previous innovation projects, and seeking to use joint procurement to achieve the scale of demand for fuel cell buses required for the industry to take the next step towards commercial deployment. At the time, zero emission buses were not widely used, but the potential of the technology to replace traditional fossil fuel powered vehicles was recognised, and many cities and regions were developing plans to phase out the purchase of diesel buses. The technical performance of hydrogen fuel cell buses had been proven, for example in the CHIC project, under which fleets of buses operated in regular fare-paying passenger service for many years in multiple cities. However, series production of fuel cell buses had not started, volumes were low, and costs were high. Furthermore, few suppliers were offering fuel cell buses, leading to a limited choice of models. Although battery electric buses started to come to market in greater numbers around this time, zero emission buses accounted for a tiny fraction of the public transport bus fleet and the amount of operational experience with the technologies was relatively limited, leading to high degrees of uncertainty regarding the real-world performance over full bus lifetimes.

Hydrogen fuel cell buses deployed to operate on the Fastway route in the Gatwick / Crawley area (UK) operated by Metrobus

Status as of mid-2023

As the graph below shows, there has been a steady growth in the number of zero emission buses in operation over the past decade. This growth has largely been driven by the uptake of battery electric buses which now account for >90% of the zero emission buses operating in mainland Europe.



Source (data): European Alternative Fuels Observatory (europa.eu) / UK Department for Transport vehicle licensing statistics (VEH1103a – battery electric + fuel cell electric buses and coaches).

There have been several positive developments in the fuel cell bus sector over the past five years. For example, when the JIVE project started (early 2017) very few bus manufacturers were offering hydrogen-fuelled vehicles, but now products are available from >10 different European manufacturers covering multiple models – single deck, double deck, articulated, and bus rapid transit solutions. Importantly, the performance of the vehicles in the JIVE projects has been good. In particular, notable progress has been made in the fuel efficiency of fuel cell buses relative to previous generations. Most JIVE buses, including double deck vehicles, are consuming less than 9kgH_2/100km, some as low as 6.5kg H_2/100km,. However, the uptake of fuel cell buses has been lower than targeted by some in the industry in the mid-2010s. For example, in 2019 the *H2Bus Consortium* announced plans to deploy 600 fuel cell buses by 2023, which together with other initiatives would have led to more than 1,000 fuel cell buses in operation. However, as of mid-2023 the number of fuel cell buses operating in Europe remains in the hundreds. A full discussion of the multiple reasons for the uptake of fuel cell buses being below expectations is beyond the scope of this paper, but one of the issues has been delays in delivering projects under JIVE, a programme designed as a steppingstone between projects demonstrating tens of buses in relatively short-term trials, and the vision of a commercial market for the technology. Until operators gain sufficient confidence in the technology it is difficult for them to commit to the larger scale orders required to unlock further cost reductions and economies of scale in the wider value chain, including hydrogen supplies.

Over this period, we have also observed a strengthening of commitments to zero emission buses. Numerous operators have announced plans to transition to fully zero emission fleets, and a range of Governments have introduced new policies and regulations. Examples include the EU Clean Vehicles

Directive[1], which defines national targets as a minimum percentage of clean vehicles obtained via public procurement across a Member State, and the European Green Deal proposal[2] for all new city buses to be zero emission from 2030.

Operational experience and data from real-world performance has increased substantially in line with the growth of the zero-emission bus fleet. This provides additional evidence for public transport authorities and operators planning the next phase of the transition to clean buses. Even bus operators who have not yet invested in zero emission vehicles can now trial the technology. For example, a hydrogen bus roadshow organised as part of the JIVE 2 project gave interested parties in central and eastern Europe the chance to trial a fuel cell bus. The vehicle performed very well and more than 90% of the cities involved have signalled strong interest in deploying fleets of fuel cell buses.

Test trials in Croatia (Zagreb) – JIVE 2 hydrogen bus roadshow

While the growth of the zero-emission bus market has been significant, with ZEBs now accounting for approximately 30% of new sales in Europe[3], the vast majority of the bus fleet still relies on fossil fuels. For example, the total number of zero emission buses registered by the end of 2022 in the UK (shown in the graph above) corresponds to <2% of the national fleet. Based on the author's experience in the sector and discussions with numerous sector experts from across Europe, most public transport authorities and operators believe that battery electric buses will continue to dominate the zero-emission bus market for the foreseeable future. This technology is an attractive solution for many routes and solutions are being developed and trialled that will allow battery electric buses to replace diesel vehicles on a one-for-one basis in an increasing range of operations. Operators of battery electric buses have the potential to benefit from fuel cost savings relative to diesel, which can make the total cost of ownership attractive, especially where fleets can be deployed without a grid connection that triggers costly upgrades in the local network. This can be possible with small fleets of battery electric buses per depot.

In contrast, making an economic case for fuel cell buses in small fleets is very challenging partly since the costs of hydrogen refuelling stations do not increase linearly with scale (station capacity). For example, the capital cost of refuelling infrastructure for a fleet of 20 buses is typically not four times the cost of infrastructure for a fleet of five vehicles. On the other hand, fuel cell buses offer greater range than battery electric vehicles and the refuelling process can be designed to be similar to refuelling diesel buses. Therefore, while the case for fuel cell buses in small fleets is often challenging, the technology is well suited to being deployed at large scale.

The operational flexibility of fuel cell buses, specifically the ability to refuel vehicles in a few minutes and the capability of many hundreds of kilometres of range (which is less severely impacted by

[1] Clean Vehicles Directive (europa.eu)
[2] 2030 zero-emissions target for new buses and trucks (europa.eu)
[3] Source: Electric city bus sales overtake diesel in Europe - International Council on Clean Transportation (theicct.org)

temperature extremes compared to battery electric buses), is a key reason for the continued interest in and commitment to the technology from some operators. Indeed, several have plans to increase substantially their fleets of hydrogen fuel cell buses over the coming years, as illustrated below (non-exhaustive list).

Operator and location	Fuel cell bus deployment plans	Reference
Brighton & Hove Buses / Metrobus, UK	A fleet of 20 fuel cell buses recently began operating on the Fastway service. The operator plans to deploy at least another 34 fuel cell buses (with support from Surrey County Council).	Metrobus HFC scheme Feb 2022 Final.pdf (surreycc.gov.uk)
RVK, Cologne region, Germany	As of mid-2023 RVK operates 52 fuel cell buses. The company's plans to scale up the fleet of hydrogen buses to >100 vehicles have been reported since 2022.	RVK orders up to 100 more hydrogen buses for Cologne - Green Car Congress
TPER, Bologna, Italy	In March 2023 TPER published a tender for 127 fuel cell buses which includes an option for a further 140 vehicles	TPER Bologna has published a tender for 127 fuel cell buses (sustainable-bus.com)

Fuel cell buses are an attractive option for operators seeking zero emission vehicles that can be operated in a similar way to diesel buses. Research published by NOW GmbH (Germany) showed that of 30 transport companies questioned, 80% require buses with a daily range of at least 200km and 20% need buses with a range of at least 350km.[4] While the former is typically within the capabilities of battery electric buses with current technology, achieving longer ranges requires hydrogen fuel cell drivetrains.

Outlook to 2030 and beyond

It is clear that battery electric solutions currently dominate the zero-emission bus space. It is also apparent that while excellent progress has been made in recent years, there is a long way to go to realise the full transition to zero emission public transport services across Europe. Operators seeking to replace entire fleets of diesel vehicles with battery electric face multiple challenges, such as limited space in depots for charging infrastructure, securing upgrades to electricity grids for whole-depot conversions, and vehicle range degradation in high / low temperatures. Of course, deploying fuel cell buses also comes with challenges and the prospect of deploying hydrogen buses is not yet sufficiently compelling for most operators to commit to the technology at the scale required for the technical and commercial case to be optimised. Nonetheless, given the operational flexibility of fuel cell buses, this is the technology of choice for specific routes and several operators around Europe have plans to deploy many tens / hundreds of vehicles within the next few years. A full transition to zero emission buses within the timescales desired by policy makers is likely to require both battery electric and fuel cell electric technologies and there are benefits to retaining multiple

[4] Innovative drives for buses in public transport: Final report compiles knowledge from three years of accompanying research - NOW GmbH (now-gmbh.de).

technology options. For example, not all duty cycles can be met with current battery electric buses, and in some locations the costs and / or timescales associated with electricity grid upgrades needed for large-scale deployment of electric buses inhibit uptake. Using hydrogen as a fuel offers an alternative way of delivering energy to vehicle fleets that does not rely on the electricity network. On the other hand, the hydrogen solution can add cost, complexity, and a different set of practical issues which must be addressed for the technology to achieve widespread adoption. Independent of the technology choice, the entire sector benefits from sharing experience and learning from pioneers. Collaboration and dissemination of lessons and best practice is crucial to accelerate the transition to zero emission bus fleets. This is why we have organised the Zero Emission Bus Conferences, a series of events which bring together policy makers, bus operators, and industry representatives to share insights, discuss key issues and form the new partnerships needed for the sector to achieve the transition to clean buses that we all want to see. The next ZEB Conference will take place alongside the Busworld exhibition in October 2023 in Brussels. Further information is available on the ZEB website.[5] It promises to be a very interesting and informative event and we look forward to welcoming a diverse range of stakeholders from across Europe and beyond.

EUROPEAN ZERO EMISSION BUS CONFERENCE

[5] Zero Emission Bus Conference | Brussels, 9-12 October 2023 (zebconference.eu)

About the author

Michael Dolman is a Partner at Element Energy, an ERM Group company. He has been working in the low carbon energy sector since 2008 and played a key role in developing and securing funding for the JIVE and JIVE 2 projects. He has overseen the coordination of this programme since 2017 and continues to support clients with the development and delivery of innovative clean energy projects.

Element Energy, an ERM Group company, is the coordinator of the JIVE and JIVE 2 projects. Element Energy has two decades' experience in the clean energy sector and as part of ERM is ideally placed to support clients with developing strategies, planning deployment of clean technologies, and implementing the solutions needed to reach net zero.

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Further reading

Guidance on initiating a fuel cell bus project: JIVE Best Practice and Commercialisation Report 3 / JIVE 2 Best Practice Information Bench Report 2 (fuelcellbuses.eu)

Joint procurement of fuel cell buses: https://www.fuelcellbuses.eu/public-transport-hydrogen/joint-procurement-fuel-cell-buses

Environmental Impacts and External Cost Benefits of FCBs – Comparison of FCBs with BEBs: Environmental Impacts and External Cost Benefits of FCBs – Comparison of FCBs with BEBs | Fuel Cell Electric Buses (fuelcellbuses.eu)

Lessons learnt from the 1st JIVE 2 CEE bus roadshow: D4.13 Lessons learnt from the 1st JIVE 2 CEE bus roadshow | Fuel Cell Electric Buses (fuelcellbuses.eu)