D4.15: Report on supply and demand for alternative FCBs in Europe – focus on articulated buses and coaches

ZERO EMISSION

JIVEs / MEHRLIN projects

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Clean Hydrogen Partnership

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Disclaimer

Contents

List of abbreviations

The table below states all the abbreviations mentioned in the report.

ADEME	Agence De l'Environnement et de la Maîtrise de l'Energie – *The French Agency for Ecological Transition*
ADL	Alexander Dennis - British bus manufacturer
AOM	Mobility Organising Authorities
BEB	Battery Electric Bus
BEV	Battery Electric Vehicle
BMDV	Bundesministerium für Digitales und Verkehr *Federal Ministry for Digital and Transport*
BSOG	Bus Service Operators Grant
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditures
CEE	Central and Eastern Europe
CVD	Clean Vehicle Directive
ERM	Environmental Resources Management - *Consultancy company.*
EU	European Union
FCB	Fuel Cell Bus
FCEV	Fuel Cell Electric Vehicle
FNTV	Fédération Nationale des Transports de Voyageurs - *National Federation of Passenger Transport*
GCK	Green Corp Konnection - *French low-carbon mobility company*
HRS	Hydrogen Refuelling Station
HDV	Heavy Duty Vehicle
ICE	Internal Combustion Engine
IDFM	Ile-De-France Mobilité
IVECO	Italian bus manufacturer
LEZ-m	Low-Emission Mobility Zones
MZA	Miejskie Zakłady Autobusowe sp. z o.o. – *Public Transport Operator Warsaw*
NGV	Natural Gas Vehicles
NOTRe	New Territorial Organisation of the Republic (FR)
NRW	North Rhine-Westphalia
OEM	Original Equipment Manufacturer
OPEX	Operating Expenses and Expenditures
ÖSPV	Öffentlicher Straßengebundener Personennahverkehr – *Road-bound public transport*
PTO	Public Transportation Operator

PTA	Public Transportation Authority
RATP	Régie Autonome des Transports Parisiens
SLO	Service Librement Organisé – *Freely Organised Services*
SME	Small and medium-sized enterprises
TCO	Total Cost of Ownership
TfL	Transport for London - *Local government body responsible for most of the transport network in London, UK.*
UITP	Union Internationale des Transports Publics
UK	United Kingdom
VDV	Verband Deutscher Verkehrsunternehmen - *Association of German Transport Companies*
ZE	Zero Emission
ZEB	Zero Emission Bus
ZEBRA	Zero Emission Bus Regional Areas

Executive summary

The JIVE 2 project and its sister project JIVE will be deploying 290 fuel cell buses (FCBs) across 16 sites in 7 countries by mid-2025. Among the deployed buses, 98% are either standard 12-meter single deck or, in the case of the United Kingdom, double deck buses. Over the course of the initiatives, the public transport operators (PTOs) and public transport authorities (PTAs) involved showed interest in other fuel cell bus models, such as articulated buses and coaches. These models will also need to transition to low- and zero-emission technologies in the coming years.

To inform future deployment decisions, the JIVE projects have conducted a study on the current and potential future demand and offer for articulated buses and coaches across different countries. This report also provides an overview of the demand for hydrogen mobility technologies in public transportation within the same geographies. The study covered countries directly involved in the JIVE and JIVE 2 projects (France, Spain, Germany, the United Kingdom and the Netherlands). It also covered countries in Northern, Eastern, and Central Europe that did not have deployment activities within the project but were actively involved in observer groups and side activities, such as regional studies and fuel cell bus roadshows.

The outcomes are drawn from survey results from PTOs and PTAs across Europe, interviews with European bus manufacturers as well as desk-based research and general learnings from the projects.

While the articulated bus assessment focused on a wider range of countries, the coach assessment focused on France. This is because the country's coach fleet represents ~70% of all buses in operation making it an interesting coach decarbonisation case study. The information included in this document is taken from a report published in October 2023 by France Hydrogène Mobilité and AVERE France, written by ERM: *La transition de l'autocar vers des technologies zéro émission : quels besoins et perspectives*.

Overall, the study concluded that the challenges faced by more popular bus models (such as 12-meter and double deck buses) are equally relevant to other hydrogen models in public transportation, including fuel cell coaches and articulated buses. The most significant challenges for PTOs, PTAs and OEMs relate to capital and operational costs, availability and reliability of refuelling infrastructure, knowledge about the technology, safety and the availability of a diverse pool of technology offerings. Even with the challenges, stakeholders in the assessed geographies are interested in trialling and deploying these hydrogen mobility technologies.

France was the pioneer in deploying articulated fuel cell buses: the city of Pau introduced 8 articulated fuel cell buses in 2019. Despite fuel cell buses only representing a low percentage of the overall French bus fleet, the numbers have been growing, and further orders of articulated models being announced (Saint Brieux, Metz, or Le Mans). The development potential is also encouraging in Germany. Several operators have started to operate articulated fuel cell buses and forecasts project the number of deployed vehicles to continue to grow in the upcoming years. However, the choice to purchase the vehicles is hindered by the uncertainty on the availability of future federal financing for zero-emission vehicles.

In Spain, although only two cities (Barcelona and Madrid) are deploying fuel cell buses, the operators are highly engaged in zero emission transport. For instance, Barcelona is already integrating articulated fuel cell bus models to its fleet.

The situation in the countries not involved in JIVE and JIVE 2 deployment activities is also noteworthy as few fuel cell buses are currently in operation. However, various dissemination and knowledge-sharing activities have revealed a strong interest in further involvement in deploying such buses. This includes the potential integration of other models, such as coaches and articulated buses, into the fleets. This interest is evident in Central and Eastern European countries, which have been actively participating in the JIVE roadshow initiatives. Northern Europe also shows interest, despite the region's significant focus on biogas and battery electric buses.

In other instances, the market for these models, particularly articulated buses, is either less relevant or not currently being pursued. For instance, in the United Kingdom, having fuel cell articulated buses is not as relevant given that the incumbent system rarely uses internal combustion articulated vehicles in public transportation. In the Netherlands, although FCB deployments have been strong over the years, the pace of further deployments has slowed down. This includes all FCB models, as the transport decarbonisation focus has shifted towards other low- and zero-emission technologies. However, expanding battery-powered transportation could significantly increase the demand on the country's grid capacity. Hydrogen-fuelled technologies can help mitigate this impact, potentially playing a more important role in the country's future public transportation.

The advantages associated with hydrogen mobility (e.g., range) is especially pronounced for coaches due to their use patterns. In France, the country case study in this report, coaches represent a large share of the buses in operation in the country (~70%); however, the market is only at its inception making it very interesting to follow as the first retrofitted models start to be homologated.

The deployment of fuel cell buses in public transportation fleets is impeded by several challenges, including costs and the availability of consistent policy support, among others. The contributors to this study have proposed several actions to be implemented to address these challenges. For instance, financial support is still heavily required, both on the side of OPEX and CAPEX, to encourage PTOs and PTAs to invest in the technology. Additionally, policies must be clear and consistent to support both OEMs and PTOs / PTAs in their decision-making. There is currently a discrepancy in policy support for urban buses and coaches. For urban buses, the framework is quite clear within legislative acts such as the Clean Vehicle Directive. However, the policies are less clear on policy support for coaches, which are for instance not impacted by the Directive.

The decarbonization of public transport will require the implementation of several zero-emission technologies. However, certain technologies may be more advantageous than others depending on the specific needs of the transport system of a country and the use cases for the buses (standard, articulated or coaches). Across Europe, there is interest for articulated and coach fuel cell models, but support from public authorities at different levels (European, national, regional, etc.) and the continuous sharing of lessons learned from past and ongoing deployment projects are essential to ensure a steady development across all models within the fuel cell bus market in the continent.

Disclaimer

Recent announcements regarding the fuel cell bus market and the status of certain original equipment manufacturers (OEMs) have emerged, particularly in relation to two key manufacturers:

- VanHool/VDL: In April 2024, Van Hool officially filed for bankruptcy, and it was subsequently revealed that VDL would acquire the company. This acquisition has significantly altered the model portfolio, as none of the previous urban bus models are currently available or listed on the company website, and there have been no announcements regarding hydrogen offerings.
- SAFRA: On February 4, 2025, SAFRA entered receivership, raising concerns about the future development of the hydrogen models within SAFRA's portfolio.

With respect to the situation involving VanHool/VDL, footnotes have been included in this report to reflect that this information was already known during the report's development. In contrast, the situation concerning SAFRA is more recent. While the core content of the report has not been updated to reflect this information, it is important to acknowledge this disclaimer.

1. Introduction

1.1 The JIVE 2 project and context for the study

JIVE 2 (Joint Initiative for hydrogen Vehicles across Europe II) is a flagship Clean Hydrogen Partnership-funded fuel cell bus deployment project. Alongside its sister project, JIVE, the two initiatives are deploying close to 300 fuel cell buses across 16 sites in 7 countries in Europe: France, Spain, the Netherlands, the United Kingdom, Italy, Latvia and Germany. The JIVE and JIVE 2 project were initiated in 2017 and 2018 respectively with the objective to advance the commercialisation of fuel cell buses through large-scale deployment of vehicles and their associated infrastructures. The fuel cell technology, along with battery electric buses, are the most widely used zero tailpipe emissions technologies to decarbonise public transportation and have been tested, demonstrated, and deployed through various European projects since the early 2000s[1]. The projects have mainly tested standard fuel cell buses (i.e., ~12-meter) and double deck buses. Amongst the buses that have been ordered in JIVE and JIVE 2, 66% are single deck buses (~12-meter), 32% are double deck buses (deployed exclusively in the United Kingdom) and only 2% are articulated buses[2].

Decarbonising the approximately 714,000[3] buses in the European Union will require not only transitioning standard 12-meter buses to zero-emission technologies but also ensuring that all other bus models are decarbonised. For articulated buses and coaches, fuel cell technology could also offer operational advantages, compared to battery electric vehicles, such as a higher range, higher passenger loading capacity and greater adaptability to difficult climate conditions (e.g., colder climates). As evidenced during the JIVE and JIVE 2 projects, PTOs and PTAs are interested in understanding these two vehicle categories, and several have begun to plan out testing to introduce such models in their fleets. The focus of this report will therefore be on these two bus categories: articulated buses and coaches.

Articulated buses are built in two or more sections, connected by hinges, and supported by three or more axles. Here, passengers can move freely between sections. For coaches, there are two categories of vehicles: 'Low Entry' and the 'Normal Floor' coaches. Low Entry coaches are classified as Class II vehicles, can accommodate standing passengers and have a similar operating profile to urban buses. Conversely, Normal Floor coaches are classified as Class III vehicles, can accommodate only seated passengers and include a luggage hold. These buses are typically used for longer trips (i.e., inter-city or cross-country).

The analysis for this report focused on deployment countries from the JIVE and JIVE 2 projects, specifically France, the Netherlands, the United Kingdom, Spain, and Germany. Additionally, the Nordic and Central and Eastern European clusters were included due to their strong connection to the projects' activities. These will be often referred to as regions in the report.

[1] European Commission, Joint Research Centre, Bravo Diaz, L., Boillot, L. (2024) Historical analysis of Clean Hydrogen JU Fuel Cell Electric Vehicles, Buses and Refuelling Infrastructure Projects – Evaluation of contribution towards the state of the art, Publications Office of the European Union. https://data.europa.eu/doi/10.2760/892745
See the FuelCellBus website: https://www.fuelcellbuses.eu/

[2] As of January 2024, the only articulated fuel cell buses are deployed in Pau, France.

[3] ACEA (December 2023). Buses Fact Sheet

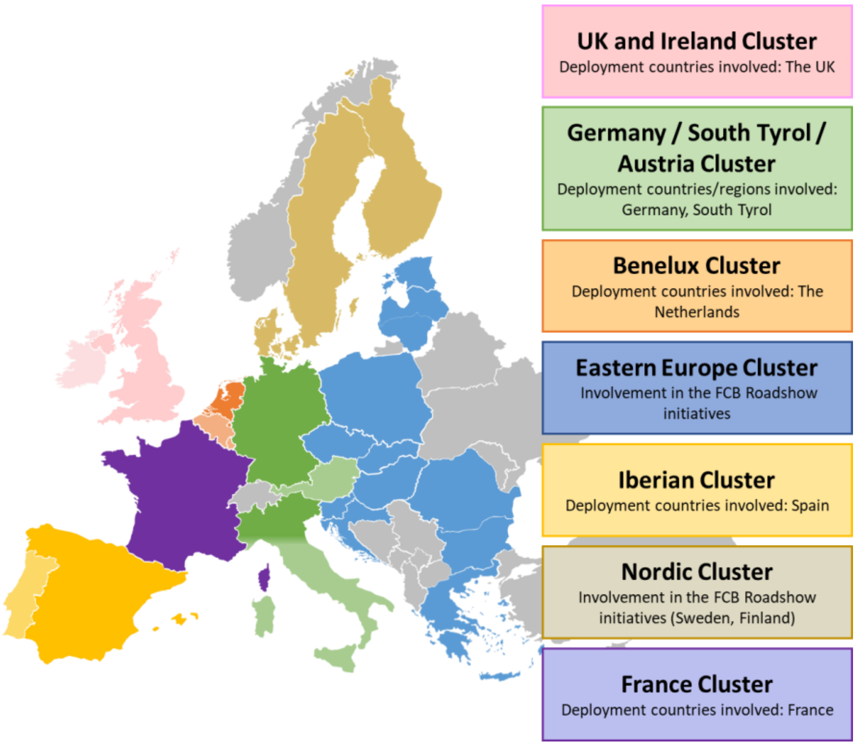

Figure 1: Map of the EU clusters included in the report (non-EU Member States have been greyed out, except the UK which participated in the JIVE projects – lighter coloured countries in each cluster are those not directly addressed in the report. For Eastern Europe, the analysis was done on a regional basis rather than a country-by-country basis)

The changes in the regulatory landscape on the decarbonisation of public transport have also led to an increased interest in other fuel cell bus models on the market. The adoption of the European Clean Vehicle Directive (EU 2019/1161) in June 2019 and its transposition into national law by the August 2, 2021, aims to promote clean mobility in public procurement tenders by defining 'clean vehicles' and setting national targets to be reached by the end of 2025 and by the end of 2030. This Directive concerns Class I and Class A vehicles[4], which includes articulated buses but excludes coaches. The table below illustrates the targets for the countries included in the clusters.

[4]Class I: Vehicles constructed with areas for standing passengers, to allow frequent passenger movement.
Class A: Vehicles designed to carry standing passengers; a vehicle of this class has seats and may have provisions for standing passengers.

Table 1: Clean Vehicle Directive national targets for buses by country

Country	Target 2021 – 2025		Target 2026 - 2030	
	Clean	**ZE**	**Clean**	**ZE**
Sweden, Denmark, Germany, Italy, the UK, Ireland, the Netherlands, Belgium, Luxembourg, Spain	45%	22.5%	65%	32.5%
Finland	41%	20.5%	59%	29.5%
France	43%	21.5%	61%	30.5%
Portugal	35%	17.5%	51%	25.5%

Despite the lack of clear regulations for coaches in this directive, other texts and policies will play a major role in the transformation of the transport sector in the future. This is the case in the implementation of low- and specifically, zero-emission zones across Europe or of the Regulation on CO_2 emission standards for heavy duty vehicles (EU 2019/1242)[5]:

- Low emission zones already exist in a vast majority of the EU countries. Although the means of implementation may differ, their objective is the same: restrict the access to certain urban areas for polluting vehicles. The Zero Emission Zones push these restrictions further by forbidding entry to all types of vehicles (through the pedestrianisation of the area) or by allowing only zero tailpipe emission vehicles (battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV)) to circulate.
- The currently enforced regulation on CO_2 emission standards requires heavy-duty vehicle (HDV) manufacturers to reduce their emissions for new vehicles by 15% by 2025 and 30% by 2030 (compared to a 2019 baseline). This original regulation did not include buses or coaches. However, in February 2023, the European Commission presented a legislative review which:
    - Extends the scope of the directive to urban buses and coaches.
    - Extends and increased the target reductions to 45% in 2030, 65% in 2035, 90% in 2040
    - Targets all urban buses to be zero emission by 2030 (this does not apply to coaches).

    In February 2024, the European Council and European Parliament negotiators reached a provisional political agreement on the revision proposal. Few amendments were suggested, including the revision of the zero-emission target for urban buses, which was postponed to 2035 with an intermediate target set at 90% by 2030, and the revision of vehicle types to

[5] Other regulations such as the AFIR (Alternative Fuel Infrastructures Regulation), the new RED II Directive (Renewable Energy Directive) or the new European emission standards may also play a role in the transformation of the coach sector.

include coaches in the regulation[6]. In May 2024, the Council of the European Union officially ratified the amendment[7].

The regions and countries involved in the JIVE projects, as assessed in this report, have experienced regulatory changes that influenced the strategies of public transport authorities and operators at various levels, including national and regional fleet decarbonisation targets and financial support. Some of the key measures and policies for each cluster and country are detailed below.

Nordic cluster: The current transport policies in Nordic countries are geared towards achieving zero tailpipe emissions in public transportation between 2028 and 2035. Several Nordic countries have already transitioned from diesel to biofuels, and the choice was driven by the technology's efficiency in harsh climates and rugged geographies. For example, regulations in Norway require new city buses to be zero-emission vehicles or biogas-fuelled by 2025 and 75% of new long-distance buses to be zero-emission by 2030 [8]. There still needs to be further government support to incentivise the vehicles' uptake. In Nordic countries, zero-emission buses are only subsidised by governments to a certain extent; however, PTOs are seeking higher subsidies and incentives.

Germany: In Germany, the Clean Vehicle Directive was incorporated into national legislation, requiring the fulfilment of specific quotas monitored at the Bundesländer (federal states) level. This entails that not every company/public transport operator must fulfil the quota. Instead, the average of all companies in a state (Land in German) that is monitored.

Additionally, the Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr - BMDV) has supported the procurement of battery, fuel cell, and battery trolley buses (covering up to 80% of the additional investment costs compared to diesel buses) as well as biomethane-powered buses (covering up to 40% of the additional investment costs compared to diesel buses) in vehicle classes M2 and M3 until 2023 through the technology-neutral 'Directive on the promotion of alternative drive systems for buses in passenger transport.' In 2023, the BMDV invested a further €53.4 million in the procurement of buses with climate-friendly drive systems and the associated infrastructure in the third funding round for clean buses. By the end of February 2024, further funding certificates were delivered to eleven bus companies and two districts from across Germany. This will put a further 186 new climate-friendly buses on the road. In total, around 4,000 buses and over 140 feasibility studies were funded under the directive, supporting over 250 transport companies and public authorities in the transition to climate-friendly public transport.

In February 2024, the BMDV announced that not all funding programs would be continued to the planned extent due to the necessary budget consolidation and the set priorities. This will also apply to the bus funding. Despite possible reduction at national level, some of the federal states continue to provide support for alternative fuel buses. North Rhine-Westphalia, for example, has been promoting electric buses (battery, fuel cell or overhead line) and infrastructure deployment (hydrogen filling stations, charging stations and the necessary workshop facilities) for many years through the Local Public Transport Act in accordance with Section 13 (1) No. 6 ÖPNVG NRW (Legislation on Public Transport). The

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[6] Council of the European Union (18 January 2024) Heavy-duty vehicles: Council and Parliament reach a deal to lower CO2 emissions from trucks, buses and trailers

[7] ICCT (May 2024) The Revised CO2 Standards for Heavy-Duty Vehicles in the European Union.

[8] Government of Norway (25 June 2021). National Transport Plan 2022-2033v

funding rate for both battery-electric buses and fuel cell buses is 60 % of the additional costs compared to a conventional diesel bus.

France: In France, the bus fleet renewal obligation, aligned with the EU targets, varies depending on the size of the urban area. In areas with less than 250,000 inhabitants, all new buses and coaches must be low emission[9] as of the 1st of January 2025. For all areas with more than 250,000 inhabitants, 50% of new buses deployed in 2025 must be zero-emission (battery electric or fuel cell electric) and the rest will need to be low-emission.

Regarding financial support from the government, the French Agency for Ecological Transition (Agence De l'Environnement et de la Maîtrise de l'Energie – ADEME) regularly launches calls for projects, such as the "Ecosystème territoriaux hydrogène" (Hydrogen territorial ecosystem), which foresees funds to support the implementation and exploitation of new hydrogen production and distribution infrastructures, and the extension of an existing hydrogen ecosystem through the deployment of new transport usages. A total envelope of €175 million was made available during the last round in 2023. In addition to national supporting schemes, some French regions also provide funding for the deployment of fuel cell buses.

Spain: Spain has established a regulatory framework with ambitious targets to support its clean energy transition. This framework, developed through the enactment of the Climate Change and Energy Transition Law in 2021, aims to achieve carbon neutrality by 2050[10]. The transport sector, which plays a crucial role in meeting the country's carbon neutrality goals, is set for significant transformation through the integration of hydrogen technologies[11]. As part of Spain's National Hydrogen Strategy, outlined in the Hydrogen Roadmap approved by the Council of Ministers in October 2020, the country has set specific targets for 2030, including the integration of 150-200 fuel cell buses and 100-150 hydrogen refuelling stations (HRS). These initiatives are supported by a €1.5 billion allocation of public funding to boost the use and production of renewable hydrogen[12]. Furthermore, pre-existing financing instruments within the European Union framework, such as Horizon Europe and the Innovation Fund Programme, have been supporting projects to develop hydrogen within Spanish transport systems.

Netherlands: Beyond the adoption of the Clean Vehicle Directive, the Netherlands has implemented the Specific Benefit Clean Air Agreement (SpUK SLA) which provides financial support to projects aimed at improving air quality and with health benefits. For 2024, a total budget of €5 million was made available. Public Transport Authorities can apply for CAPEX funding for a minimum of 10 zero-emission buses. The grants amount to €75,000 per vehicle for FCBs, zero-emission articulated buses or coaches and €25,000 per vehicle for a battery-electric bus.

United Kingdom: The UK Department for Transport (DfT) has consulted in both 2021 and in 2022 on ending the sale of new, non-zero-emission buses, and in both consultations, the DfT has suggested dates between 2025 and 2032. For coaches, this date is expected to extend to 2040. As of May 2024, a

[9] Technologies included in the definition of low-emission: battery electric, fuel cell electric, 100% electric trolleybuses, gaseous fuel if a fraction of the gas consumed is of renewable origin, electric-hybrid vehicles powered exclusively by a fuel of predominantly renewable origin, gaseous fuel*, electric-hybrid*, vehicles using exclusively a fuel of predominantly renewable origin, or a synthetic or paraffinic fuel* (* the last three are only applicable to certain zones).

10 IEA (last update 18 November 2022). Climate change and energy transition law – Policies

11 https://doi.org/10.1016/j.ijhydene.2023.05.154V.M. Maestre, A. Ortiz, I. Ortiz (25 December 2023) Decarbonizing the Spanish transportation sector by 2050: Design and techno-economic assessment of the hydrogen generation and supply chain (International Journal of Hydrogen Energy, Volume 48, Issue 99) https://doi.org/10.1016/j.ijhydene.2023.05.154

12 Watson Farley & Williams (30 March 2021). The Spanish Hydrogen Strategy

decision has not yet been communicated. Nevertheless, some targets have been set by the Mayoral Authorities in England, with most planning for a full fleet decarbonisation by 2040 latest and several targeting 2030.

In the UK cluster, several funding schemes are available and directed at providing financial support for Zero Emission Buses (ZEBs) CAPEX costs. These have predominantly been directed at original equipment manufacturers (OEMs) looking to develop their sustainable offerings. The UK government has no specific stance in supporting electric or fuel cell buses, with both the technologies being considered within the same frameworks.

The main funding schemes in the UK cluster are the following:

- England (excluding London): ZEBRA 2 is a funding scheme that closed its latest round in December 2023. The scheme provided CAPEX support for zero emissions buses across England. The scheme has shown to be under-funded and over-subscribed due to the high interest from OEMs looking to develop their zero-emission bus offerings.
- Scotland: ScotZEB fundings' latest round also closed in the end of 2023. However, no decisions have been announced yet. The scheme is similar to ZEBRA 2 and has also received high interest from eligible OEMs.
- Northern Ireland: In Northern Ireland, the dominant operator is owned by the UK government and is funded via the Northern Ireland Department for Infrastructure with ZEB funding.
- Wales: there are no specific funding programmes in Wales as the bus reform policy is still under debate.

Moreover, operational support is available through the Bus Service Operators Grant in England, the Bus Services Support Grant in Wales, and the Network Support Grant in Scotland, which are existing mechanisms enabling zero-emission buses to benefit from favourable revenue support rates where services are operated commercially.

Central and Eastern Europe: The Central and Eastern Europe (CEE) cluster is made up of 12 countries: Latvia, Lithuania, Estonia, Poland, Czech Republic, Croatia, Greece, Slovakia, Slovenia, Romania, Hungary and Bulgaria. Although the CEE countries have been less advanced than Western and Northern European countries, various countries or cities in the region have tackled the necessity to decarbonise their public bus fleets in recent years. Initiatives such as the JIVE 2 bus roadshow, which showcased FCBs in various CEE countries, have helped to increase interest in this technology among many cities, as witnessed by the announcements following the event confirming the interest of several cities in ordering hydrogen-powered buses. However, as the cluster brings together many countries, the ambitions of these different countries to decarbonise their public bus fleets vary widely. Romania, for example, has no official target for decarbonising its public bus fleet in Bucharest, while in Estonia, the city of Tallinn is aiming to have a diesel-free bus fleet by 2025, and to be zero-emission by 2035[13]. Poland has set specific targets for the FCBs technology: a first target is set for 2025 (launch of hydrogen powered zero-emission buses with 100 to 250 new FCBs) and a second is set for 2030 (800 to 1,000 new FCBs) both describe the expected level of FCBs and HRS deployment[14].

[13] Tallinn 2035 Development Strategy
[14] Ministry of Climate and Environment (December 2021) Krajowy Program Ochrony Powietrza (Update of the national air protection program)

1.2 Data collection methodology to the report

To account for differences between European regions, the study was led at a cluster and country level by the cluster coordinators involved in the JIVE 2 project. The methodology used was two-fold and included online questionnaires prepared for both the demand and supply side, combined with follow-up interviews when possible.

Two questionnaires were developed by the project coordinator ERM and the cluster representatives and adapted to be shared with PTOs and PTAs (i.e., demand side) and OEMs (i.e., supply side). These were shared to the relevant contacts within the clusters and, when needed, the questionnaires were translated to the local language. The main topics addressed in the questionnaire were:

- General fleet information and transition to zero emission solutions
- Articulated bus fleet operation and fuel cell technology (barriers and enablers)
- Coach fleet operation and fuel cell technology (barriers and enablers)

In some instances, and when possible, post-questionnaire interviews were scheduled to dive deeper into the provided answers and collect further insights. In the end, both the questionnaire and the subsequent interviews yielded information into the strategies of different organizations and their overall perception of the market. The overall insights were backed by desktop research. When required by the interviewee, the outcomes of the discussions were anonymised.

For two clusters, the approach needed to be adapted to account for the lower-than-expected engagement with the study from interviewees and stakeholders, for the specificities of the region or for the lower maturity of the fuel cell vehicle market. Information was therefore gathered through desk-based research. This was the case in particular for the United Kingdom and Central and Eastern Europe.

1.3 Objectives of the study

This study aims at investigating the potential market for fuel cell articulated buses and coaches, understanding, across the different regions, how and where these types of buses are deployed, and the perception of the hydrogen technology applied to these models. Additionally, the status of the existing offers on the market and the stance taken by the involved OEMs has been tackled.

This report is divided into 4 main sections:

1) Focus on articulated buses from a PTO/PTA and supply point of view.
2) Focus on coaches from a PTO/PTA and supply point of view.
3) Focus on regional specificities.
4) Deep dive into the barriers and enabling factors.

The questions which the report aims to provide an answer to in each section therefore are:

- Are fuel cell buses already deployed in those clusters?
- What importance do articulate buses and coaches have in the overall national fleets?
- Are local Public Transport Operators/Public Transport Authorities considering fuel cell articulated buses and coaches for future deployments for their decarbonisation strategies?
- What are the barriers which impede the further deployment of such buses and what potential solutions exist?
- How does the demand/offer landscape look like for these models as of late 2023 and how could it develop in the future?

The report will bring a high-level view of the status with regards to supply and demand of these two niche segments of the bus sector. More detailed analysis could be conducted in follow up reports.

2. Articulated buses

2.1 Introduction

The following section will focus on articulated buses. Articulated buses are primarily utilised on interurban and city routes in densely populated areas, with daily distances typically ranging from 200 to over 250 km. These buses aim to provide high-frequency service, operate over extended hours, and accommodate a higher passenger density with the ability to carry over 150 passengers. These models can also serve suburban and regional routes.

Given political engagements set at a European and national level to decarbonise the public transportation, PTAs and PTOs must consider the transition for all bus types, including articulated buses. These types of buses have seen some increase in some countries as public transportation is also looking to increase in efficiency and utilisation.

After the deployment of the natural gas, hybrid and electric articulated bus, the fuel cell articulated bus is now being launched on the bus market to help decarbonise vehicle fleets. As of 2023, their deployment in Europe is only at its premise, with three European manufacturers currently commercialising and delivering articulated fuel cell buses (Mercedes-Benz, Solaris and Van Hool[15]). Other manufacturers have announced plans to expand their fuel cell vehicle portfolio in the upcoming years and include articulated models.

The organisation and operation of public transportation (all bus models included) varies by cluster and by country. Generally, however, Public Transportation Authorities (PTAs) oversee, plan, and regulate public transport in their areas and therefore drive demand and commissioning of vehicles. The operation of the buses can be carried out by the authority themselves or by a Public Transportation Operator (PTO). Both entities have been targeted by this study to identify advantages of hydrogen-powered articulated buses as well as potential future demand and barriers to deployment.

Operators and manufacturers have pinpointed several key obstacles currently affecting the deployment of articulated hydrogen buses, such as the overall expense and high CAPEX of the technology, limited knowledge of its functioning, shortage and unreliability of refuelling infrastructures, and limited offering from Original Equipment Manufacturer (OEMs). These obstacles concern fuel cell buses in general.

To present a more comprehensive overview of the status of fuel cell bus articulated market, as well as possible future deployment, the following sections will dive into each cluster specificities when it comes to articulated buses and fuel cell technology. The last section will in parallel present an overview of the European current and future offer of these vehicles.

2.2 Demand-side analysis of the European vision for fuel cell articulated buses

[15] In light of Van Hool's bankruptcy announcement in April 2024 and its subsequent acquisition by VDL, the urban bus models formerly available from Van Hool are no longer featured on the manufacturer's website. The current emphasis is on coaches and no hydrogen models are being offered at this time.

The following section presents a cluster-by-cluster overview of the articulated bus market and the overall status with regards to the development of hydrogen technology within this specific niche and more widely in the bus sector.

Nordic cluster

The Nordic cluster is made up of four countries: Denmark, Finland, Norway, and Sweden. According to the ACEA 2022 data, around 50,000 buses and coaches were in operation across the region (~15,500 in Norway, ~14,000 in Sweden, ~8,500 in Denmark, ~11,000 in Finland)[16].

The public bus transportation sector is organized similarly across these Nordic countries: a combination of PTAs outsourcing operations of the fleet to private PTOs. In this framework, public service contracts play a major role in regulating the market; competition may vary from region to region, but overall quality and safety standards are kept on a similarly high level. These countries place great emphasis on accessibility of the structures, punctuality of the service, and passenger comfort for their public bus transportation, making it a popular and efficient mode of travel throughout the Nordic region.

In the framework of this study, the cluster coordinator reached out to 37 organisations, including both PTOs and PTAs, which lead to 17 questionnaire answers and 7 interviews organised with a majority of responses coming from actors in Sweden. As it was observed, PTAs were generally more inclined to participate in the study and share information.

Overall, the reached organisations manage a cumulative fleet of up to 10,000 buses (all models and technologies included). This also includes articulated buses, which are operated by several of the organizations involved in the study, for a total cumulated number of approximately 2,500 units (i.e., 21.7% of the total fleet on average per operator). These are mostly used in densely populated areas, such as trunk lines and city routes (Class I – Class A) where they are planned to have a high frequency, broad operation time and carry a higher number of passengers. In some isolated cases, articulated buses are also deployed on suburban and regional routes. Ownership of these buses is primarily held by a minority of organizations, with leasing being the preferred option.

The graph below portrays the choice of technology across the surveyed Nordic fleet (excluding diesel vehicles).

[16] ACEA (February 2024) Vehicles on European Roads

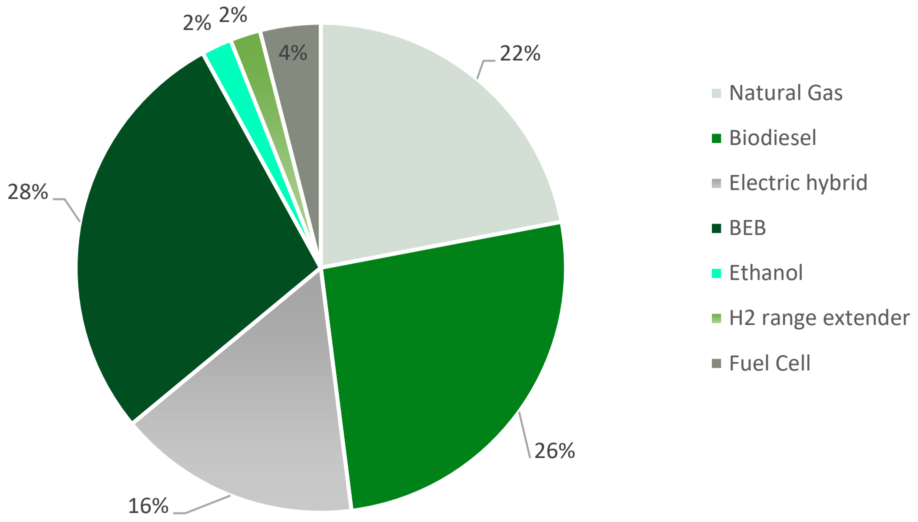

Figure 2: Choice of technology for the surveyed Nordic fleet (excluding diesel).[17]

A great majority of the buses in the Nordic fleet that are expected to run on natural gas are fuelled with biogas instead. Hence, as highlighted by the above diagram, biofuels (natural gas and biodiesel) account for approximately 48% of fuel sources for the surveyed cluster bus fleet. Battery electric buses (BEBs) are the second most used technology with 28% of the total and remains, according to participants to the study, the most "cost-effective" solution thanks to its lower TCO. Hybrid vehicles are also a broadly used technology representing 16% of the bus fleet. Diesel still represents the vast majority of bus fleets. For instance, in 2023, more than 93% of the buses running in Finland were diesel and around 6% were battery electric buses[18]. In Denmark, the distribution is similar with 91% being diesel and around 7.5% battery electric[19].

Currently, only two of the participant organisations are operating fuel cell buses on a trial basis. This limited development can partially be explained by the lack of hydrogen refuelling infrastructure in the region. Nordic countries have had a slower deployment rate of hydrogen refuelling infrastructures compared to other European regions: only 3 countries in this cluster (Norway, Denmark and Sweden) have deployed stations to a limited extent, whereas Finland is only now starting the development of a hydrogen value chain and ecosystem. As a supporting example of this obstacle, one organisation surveyed operating in Denmark was unable to complete trial of fuel cell buses after the withdrawal of the deployment of a hydrogen refuelling station (HRS).

When it comes to future deployment plans, market trends indicate clear objectives in the short-/medium-term (i.e., up until 2035) to increasingly include zero tailpipe emission technologies but the longer-term portrait remains quite unclear. As an outcome of the study carried out, the Nordic bus fleet

[17] The data comes from operators interviewed in the cluster.
[18] The Finnish Information Centre of Automobile Sector. Statistics – Bus fleet by fuel type
[19] Statistics Denmark, Stock of buses as per 1 January by propellant and gross weight

surveyed does not expect significant market growth in terms of their total bus fleet. As depicted in Figure 3, only an increase between 10 and 14 percent of the current bus fleet is expected by 2035 (representing a Compound Annual Growth Rate – CAGR – of only 1.1% per year).

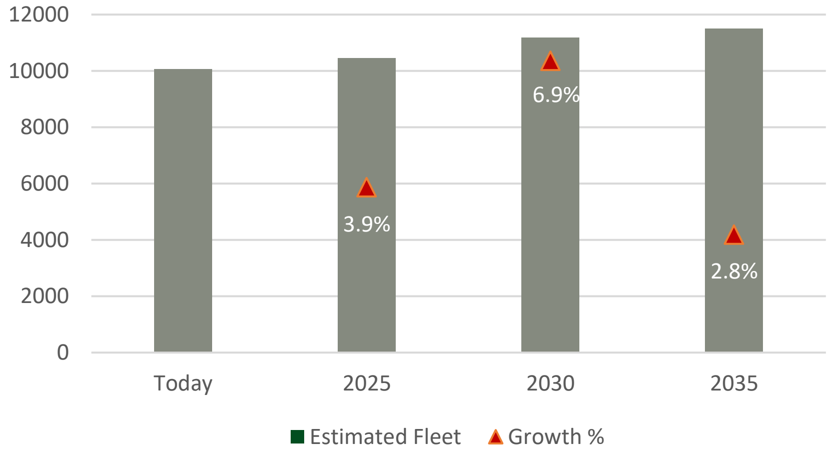

Figure 3: Current Nordic cluster bus fleet and forecasted growth[20]

However, in contrast with the low growth rate of the bus market, the estimated growth of zero-emission technologies in the current and future fleets of the surveyed group is expected to reach up to 420% by 2035, as shown in Figure 4, with a CAGR of approximately 14.8% yearly from 2024.

In the Nordic cluster, a large-scale replacement operation of old buses in favour of low- and zero-emission vehicles is already taking place and can be expected to continue after 2024. Though the market itself is not truly expanding, technology is being replaced to meet zero-emission buses objectives which have been clearly adopted by most PTAs surveyed, resulting in diesel no longer being the regularly chosen fuel already today.

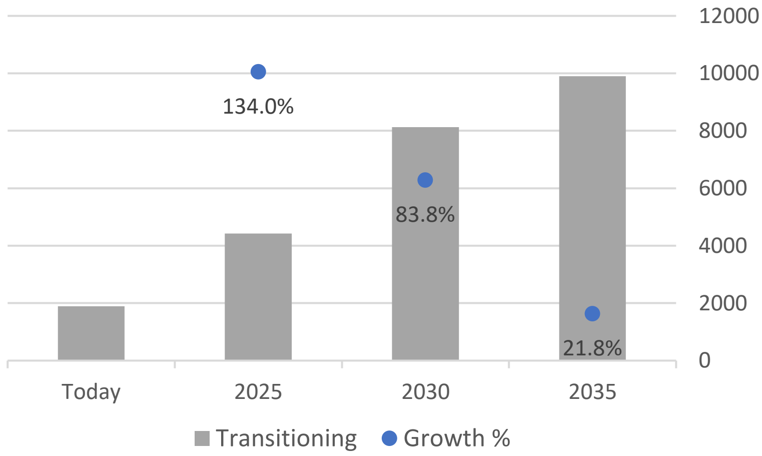

Figure 4: Current Nordic zero emissions fleet and transitioning expected growth (for surveyed group)

[20] Graph based on the on the 17 responses received from PTAs/PTOs by the Nordic cluster to the questionnaire, Autumn 2023.

As per the preferred technologies to be adopted during this transitioning phase, the results to the survey have shown that, when it comes to fuel cell buses, PTOs are still uncertain about these investments. This is due mainly to two factors. On the one hand, although PTAs have clear short-term objectives for transitioning towards zero-emission buses, they remain technology neutral. On the other hand, typical PTO contracts in Nordic last for an average of 10 years, leading PTOs towards prioritizing more established and less costly zero-emission technologies, like BEBs, rather than fully considering hydrogen options.

Development of the fuel cell buses market in the region can still be expected, as testified by an expected trial of fuel cell buses in Sweden as of winter 2024. However, when it comes to articulated buses, only 5 out of the 17 surveyed organisations expressed interest for possible trials, whilst still highlighting that BEBs remains the preferred technology for this type of bus by PTOs. It is worth highlighting that estimations on the future role of fuel cell articulated buses are made particularly difficult in the region by a basic lack of certainty on the evolution of this specific category in the overall regional market.

German cluster

In Germany, road-bound public transport (in German öffentlicher straßengebundener Personennahverkehr or ÖSPV) is managed by local authorities such as districts and cities. These act as PTAs and often appoint either their own ordering organizations (private entities) to coordinate operations of the local public transport or transfer this role to transport (or tariff) associations. The latter, even when not involved in the coordination of transport operations, are very common in Germany and play an important role in local public transport as they encourage easy access to public transport for passengers by establishing uniform tariffs for all transport companies of the same region.

Within the Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen - VDV), there are approximately 200 companies operating exclusively buses, alongside 100 additional firms operating buses but also other transport services. Collectively, they manage a fleet composed of 24,011 owned buses and an additional 9,833 rented buses[21]. It is worth mentioning that also amongst interviewed operators, 85% own their buses (including articulated buses).

The below diagram represents the different bus models operated by the German PTOs/PTAs in 2022.

[21] Verband Deutscher Verkehrsunternehmen (VDV). (2022) Statistik

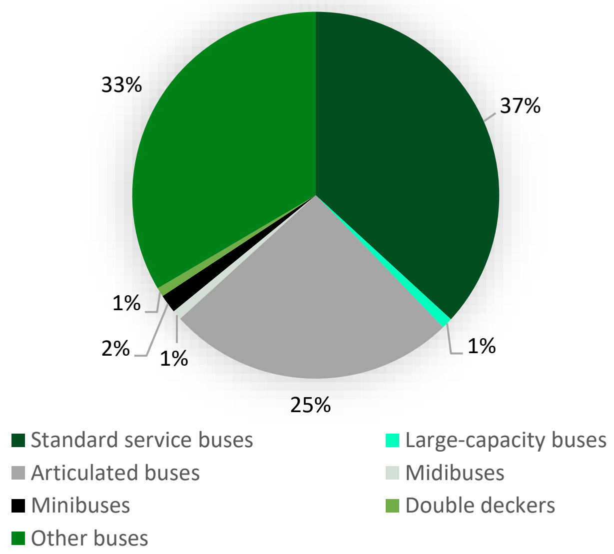

Figure 5: German cluster bus breakdown in 2022 (VDV data).

Standard service buses and articulated buses make up for 62% of the entire German bus fleet. This represents 8,623 articulated buses in operation in 2022 and an additional 329 high-capacity buses (i.e. buses measuring more than 18.75 meters). The extensive use of articulated buses has been confirmed by the study's survey, where all 13 surveyed PTOs/PTAs stated they currently operate between 1 and 150 articulated buses, each out of fleets spanning between 50 and 300 buses. Articulated buses therefore represent a significant subset of the national fleet.

As far as the use of different technologies is concerned, in Germany almost 4,000 buses out of 34,000 use alternative propulsion systems. The predominant trends in the market involve the adoption of battery-electric buses and natural gas technologies. Hydrogen-powered buses, on the other hand, still constitute a minority, representing only 1% of the total bus fleet (vs. 5% for other electric models)[22].

The German articulated bus market is following the country's major trend, with the gradual shift towards low-emission technologies, driven by stringent environmental regulations and sustainability goals. Battery-electric buses are gaining traction due to advancements in battery technology, offering zero-emission operation and reduced maintenance costs. Nevertheless, according to the survey results, most operators indicated a daily range requirement of 200 km or even 250 km, which clearly advantages hydrogen fuel cell buses thanks to their longer range, making them suitable for longer routes and areas with limited charging infrastructure. Other advantages highlighted by the respondents include the higher passenger capacity, lower net weight and shorter refuelling time.

Both technologies align with Germany's ambitious targets for reducing greenhouse gas emissions and promoting clean transportation solutions. As a result, local manufacturers and operators are increasingly investing in electric and hydrogen-powered articulated buses to meet regulatory requirements.

As far as future deployments are concerned, the country's fleet of articulated buses according to the surveyed operators is expected to increase by 2035, with most respondents estimating a future share of articulated buses spanning between 50 and 80 percent. By the end of 2024, the overall proportion of hydrogen-powered buses in the current German fleet of articulated buses is expected to vary up to 17%.

[22] Verband Deutscher Verkehrsunternehmen (VDV). (2022) Statistik

At the cluster respondents' level, only 15% currently operate fuel cell articulated buses or target to bring fuel cell buses into operation in 2024.

In addition, it is worth mentioning that independently from the results of this survey, 2023 and early 2024 already saw a significant increase in the deployment and commissioning of fuel cell articulated buses. According to recently published press releases, a total of 64 FC articulated buses have been deployed or ordered, notably: 25 buses deployed in Mannheim[23], 5 buses for Rebus Rostock[24], 13 buses for WSW Wuppertal[25], 18 buses for RVK Cologne[26], and 3 buses for Bremerhaven[27]. The results from an internal survey[28] within the German fuel cell bus cluster executed in spring 2024 on behalf of NOW however indicates that the number of FCBs will increase significantly until end of 2025. Including the buses that have been ordered already, another 574 solo buses and 185 articulated buses will begin operations. The operators have expressed the intention to procure even more fuel cell buses in 2026 and beyond; however, this will depend on the experiences they will have with the current buses, the evolution of hydrogen and fuel cell bus prices and finally on the availability of funding schemes.

Overall, it can be stated that there is currently a strong interest in Germany for fuel cell articulated buses and this can be expected to increase in the near future.

Benelux Cluster

The Benelux cluster include the deployment country of the Netherlands, as well as Belgium and Luxembourg. As part of the study, the Benelux cluster coordinator interviewed three operators in Belgium and the Netherlands and provided results for Luxembourg based on desktop research. However, the focus will mainly be on the Netherlands.

In the Netherlands, the operators are categorised into two groups: three public operators coordinate public transport in the metropolitan regions of Amsterdam, The Hague, and Rotterdam, whilst other country regions are coordinated by private operators. In both cases, the operator owns the buses, which are tendered by the public transport authority (PTA) typically on a 10-year concession contract.

In Belgium, there is a more complex system that combines public authorities and private subcontracted operators. De Lijn is responsible for the bus operations in Flanders and subcontracts the regional bus lines. STIB buses operate on the territory of the Brussels-Capital Region. Lastly, TEC handles the bus traffic in Wallonia. In Belgium the majority of the buses are owned by the operators directly.

Comprehensive bus services linking the towns and villages of Luxembourg are contracted out to private operators by the RGTR (Régime Général des Transports Routiers) under the Ministry of Transport. Luxembourg City is served by 163 of its own AVL (Autobus de la Ville de Luxembourg) buses. As with the RGTR, AVL contracts out to private operators for a number of services, while most of these buses are in AVL colours.

[23] Sustainable Bus (24 November 2023). The first 3 eCitaro G fuel cell from series production have been delivered in Rhine-Neckar region

[24] Urban Transport Magazine (22 April 2023). 52 Solaris hydrogen buses for rebus in Güstrowv

[25] Energie und management (19 July 2023). Wuppertal buys 32 new fuel cell buses.

[26] RVK (23 August 2023). RVK is renewing its bus fleet with Solaris Urbino 18 Hydrogen articulated buses

[27] Diersch & Schröder. Green hydrogen for Bremerhaven

[28] To be noted: the result of this survey is not yet published.

In 2022, ~5,200 buses (excluding coaches) were deployed in the Netherlands[29], of which approximately 900 are articulated buses, representing 17% of the entire national fleet[30]. These are mostly deployed in urban areas, where operators can benefit from their higher passenger capacity, and don't require an important higher mileage. The below graph shows the number of articulated buses per technology.

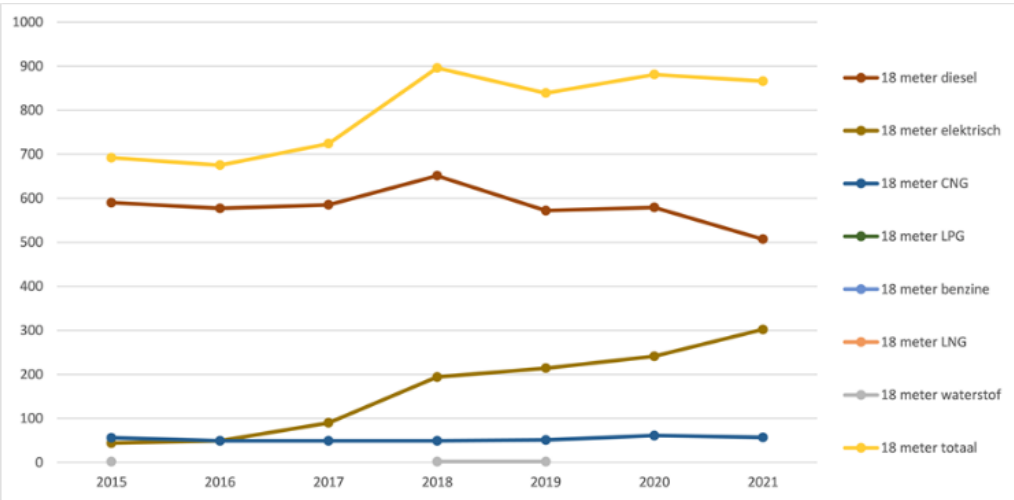

Figure 6: Choice of technology for the fleet of 18-meter Dutch buses in 2021[31].

Up until 2021, diesel articulated buses still represented most of the fleet. However, the country's effort to go towards net-zero public transport can already be seen, with articulated BEB increasing in number from 2017 onward against a decrease of diesel buses deployed.

When looking at recent and future deployment of vehicles in the Netherlands, public transport authorities require zero-emission buses in their new tenders, in line with the national goal of deploying only zero-emission new vehicles from 2025 onward and achieving a full zero-emission national public fleet by 2030. This has resulted in a current national fleet of approximately 2,000 zero-emission vehicles out of the ~5,200 buses of the national fleet[32]. No preferences in terms of zero-emission technologies to be deployed are set by the PTAs, leaving the choice to the operators. The concession tenders put out by the PTAs are often between 10- to 15-year contracts. Most concessions over the past year addressing the decarbonisation of public transportation fleets have focused on battery electric buses, causing a lock-in for this technology during the time of the concession. The lower CAPEX and OPEX costs as well as the currently more developed charging infrastructure network make BEBs the most common choice for PTOs. Additionally, as testified by the interviewed participants in this study, the choice of technology is indeed driven not by the type of vehicle (12- or 18-meter) but rather by the deployment routes and operational schedules. As previously mentioned, articulated buses in the Netherlands are mostly deployed in urban areas and on routes where a higher passenger capacity is needed, rather than suburban and regional areas where long distance driven is the main factor. Therefore, the battery electric models (whether it be for standard buses or articulated buses) often answer to the requirements of the operator.

[29] KpVV CROW, Environmental performance buses 2022
[30] https://rwsduurzamemobiliteit.nl/beleid/routeradar/mmip-duurzaam-toekomstbestendig-mobiliteitssysteem/routeradar-innovatiemonitor-marktontwikkeling/bussen/
[31] Ministry of Infrastructure and Water Management (Netherlands), Sustainable Mobility - Buses
[32] KpVV CROW, Environmental performance buses 2022

Nevertheless, fuel cell buses have been deployed in the Netherlands, with ~60 vehicles already on the road, all under the framework of the JIVE projects. All the buses are standard buses, and no articulated buses are currently in operation.

Demand for hydrogen in future deployments is also quite difficult to foresee. The SPUK regulation in the Netherlands provides a €5 million budget for decarbonising the public transport fleet for 2024. PTAs can apply to reduce their CAPEX costs for a minimum of 10 vehicles: battery electric buses are financed at 25,000€ and hydrogen buses at 75,000€. However, according to the interviewed PTOs, the majority of costs linked to deploying hydrogen vehicles is operational and maintenance costs, which are not covered by national funding, making battery electric the preferred option by PTAs requesting funding, as the TCO comparison between the two technologies over 13 to 15 years (i.e., the duration of the concession) is still too unbalanced.

In Belgium, the implementation of zero-emission buses goes in a similar direction although at a slower pace, especially when looking at hydrogen. In 2023, 282 zero-emission buses BEBs were registered in the national fleet[33]. De Lijn, the PTO operating 3,433 buses in the Flanders region, has set the goal to have a full zero-emission fleet by 2030, and is currently focusing only on the deployment of battery electric buses. As far as hydrogen is concerned, 5 hydrogen buses are currently deployed in Antwerp. Similarly, in Luxembourg operators are also decarbonising their fleets with BEBs (~100 in total)[34] but have not yet deployed any hydrogen vehicles.

It can be concluded that the current demand for hydrogen buses in the Benelux cluster, especially for articulated buses, is relatively low, as PTOs are focusing on deploying battery electric vehicles. The main factors influencing this decision, according to the interviews carried out in the framework of this studies, are 1) the nature of routes served by these specific vehicles (notably urban routes with a high number of passengers, but low mileage and average speed), for which the requirements can be easily met by BEBs, 2) the higher CAPEX and most importantly OPEX of the hydrogen technology, which are currently not supported by national funding, and 3) the nature of concession contracts used in the region, spanning from 10 to 15 years, which create a lock-in effect. In addition, limited maintenance infrastructures and a low availability of the hydrogen refuelling stations have also been mentioned as limiting factors during the interviews. Hydrogen buses are deployed only when battery electric vehicles cannot meet the route requirements (i.e., 12m buses deployed in suburban or regional routes).

However, when looking at the large scale and country-level system, there is space for a wider deployment of fuel cell vehicles, and this has been confirmed by the results of the study. Indeed, in the Netherlands, increasingly limited grid capacity is becoming a growing problem, preventing an effective organisation of charging periods of the battery electric buses in the operational schedule. Applied on a large scale, fuel cell vehicles can support relieving the electricity grid if the hydrogen is produced during less high intensity electricity consumption periods. A Community of Practice for fuel cell buses in the Netherlands was launched by the cluster coordinator which was expected to allow wider communications on the benefits of adopting hydrogen vehicles on a large scale. The future demand for hydrogen buses could therefore change drastically if the above-mentioned key challenges, notably availability of maintenance structures and HRSs, as well as hydrogen price per kg, are resolved.

[33] Sustainable Bus (11 January 2024). 282 zero emission buses are operating in Belgium today, with plans for further 300 in 2024-25

[34] Sustainable Bus (16 January 2021). In Denmark, Luxembourg and Netherlands over 2/3 of bus registrations are ZE

France Cluster

France is Europe's 3rd largest market for buses and coaches in operation in the European Union and United Kingdom territory (after Poland and Italy), with a fleet of 94,000 vehicles all bus models included and around 27,400 buses (i.e., coaches are not counted in this figure)[35]. Decarbonising the public transport fleet is therefore a major concern for this country. Among these vehicles, articulated buses – which represent more than 4,000 buses in 2022[36] – will also need to transition to low-/zero-emission solution all the while continuing to provide the required service. These buses, as previously mentioned, are often operated under more intensive conditions (long service hours, high-speed routes, etc.). The graph below depicts the breakdown of bus types (excluding coaches) in France in 2022, highlighting the important market share of articulated buses in this cluster.

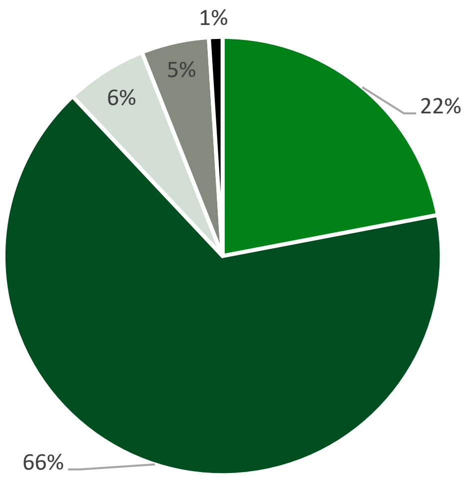

Figure 7: Breakdown of urban bus types operated in the French cluster as of January 1st, 2022.[37]

A growing share of the buses in the national fleet are low-/zero-emission vehicles. This transition is largely driven by fleet renewal policies (see details in the introduction) which set targets for low- and zero-emission bus deployment, such as natural gas, hybrid, battery electric or fuel cell buses.

In France in 2022, more than half of the articulated buses were diesel. The main alternatives were natural gas vehicles (NGVs) and hybrids (see graph below).

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35 ACEA (February 2024) Vehicles on European Roads

36 UTP (Union des Transports Publics et ferroviaires) (October 2022). Le Parc des Véhicules des Services Urbains au 1er janvier 2022 (*Urban Services Vehicle Fleet at January 1, 2022*)

37 UTP (Union des Transports Publics et ferroviaires) (October 2022). Le Parc des Véhicules des Services Urbains au 1er janvier 2022 (*Urban Services Vehicle Fleet at January 1, 2022*)

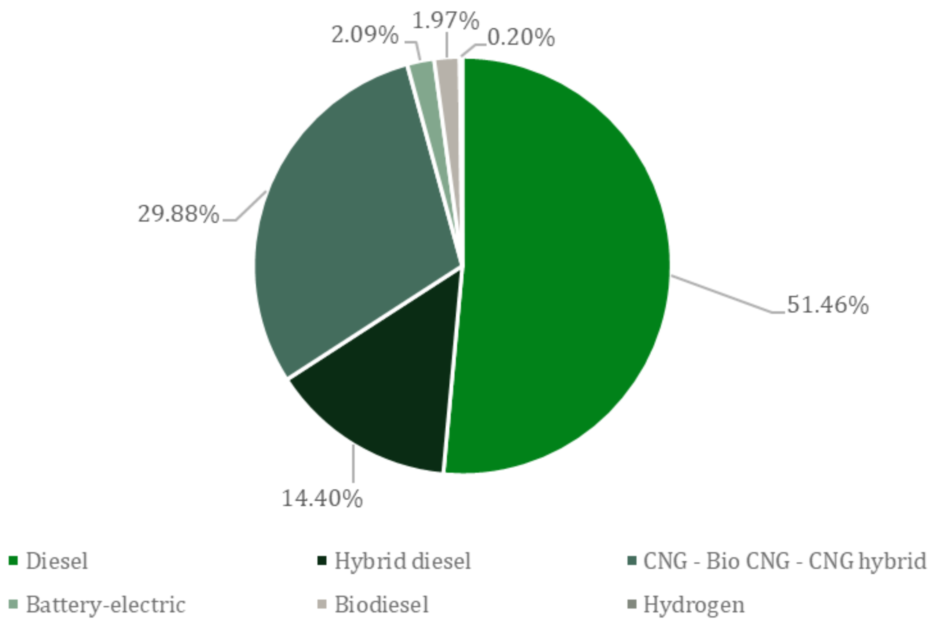


Figure 8: Articulated bus – breakdown per energy used – as of January 1st, 2022[38].

To better understand the French cluster market, interviews have been conducted with 2 out of the 3 main French operators, Keolis and RATP, and questionnaires have been distributed to, and completed by, 12 French PTOs/PTAs out of the 46 entities contacted which also included community of communes, local urban authorities and joint transport association.

When it comes to meeting the decarbonisation targets set at a European and national level, the interrogated PTOs/PTAs generally favour the deployment of battery electric and natural gas vehicles over hydrogen fuel cell buses whether it be for standard (~12m) or articulated (>18m) models. This feedback aligns with the status of distribution of the French bus fleet in terms of drivetrain. Nevertheless, one third of the questionnaire respondents identified hydrogen technology as a potential solution to help reduce their overall fleet carbon footprint in the future. In most cases, the integration of this technology in the fleets is being carried out in stages, starting with small-scaled deployments focused on 12-meter buses before increasing the overall fleet number and expanding the hydrogen deployment projects to other vehicle types such as articulated buses.

When looking more specifically at the three main operators in France – Transdev, Keolis and RATP – all have begun to operate fuel cell buses. However, as of today, these tend to be small scale deployments of standard 12-meter models.

Since 2015, Transdev has been testing the hydrogen technology across its fleet of city buses. By 2025, the operator plans to have a fleet of 90 to 100 fuel cell buses. Regarding their overall objectives, Transdev currently has 3,000 zero-emission vehicles and aims to continue transitioning these to greener vehicles, with the aim of reducing their overall carbon emissions by 30% by 2030.

The RATP, especially through its subsidiary RATP Dev which manages the operation and maintenance of public transportation outside of the Île-de-France region, has been involved in several first-time fuel cell bus deployment projects across France. An example is the deployment of two fuel cell buses in la Roche-sur-Yon between 2021 and 2022. In the Île-de-France region, RATP has been highly active in planning

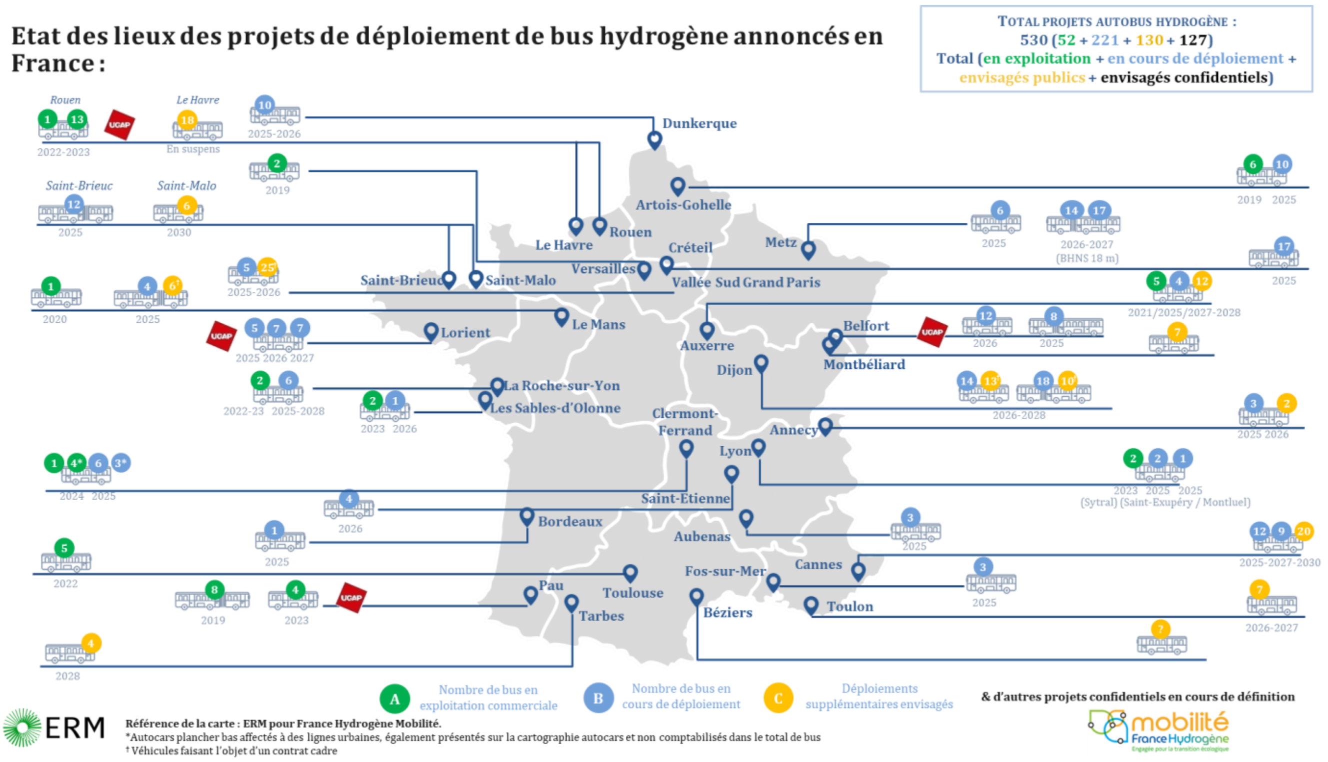
[38] UTP (Union des Transports Publics et ferroviaires) (October 2022). Le Parc des Véhicules des Services Urbains au 1er janvier 2022 (Urban Services Vehicle Fleet at January 1, 2022)

the decarbonisation of their fleet. This is reflected in the establishment of the BUS2025 initiative back in 2014. Its aim is to renew the entire bus fleet operated by the RATP on behalf of Île-de-France Mobilité by converting 50% to battery electric and the other 50% to biogas. Hydrogen was not foreseen to be part of this plan. Nevertheless, the integration of fuel cell buses is already planned in the Greater Paris with for instance the operation of 17 FCBs in Créteil by the RATP on behalf of Île-de-France Mobilité expected in 2025. Overall, the RATP decided to first focus on exploring the possibilities of introducing standard 12-meter fuel cell buses in suburban areas before considering the integration of fuel cell articulated buses in their fleet.

Lastly, as of 2023, approximately 20% of the bus fleet operated by Keolis is powered by alternative energies, comprising over 2,000 buses running on battery electric technology and approximately 20 utilising fuel cells. In France, and similarly to the other PTOs, Keolis's decarbonisation strategy is mainly focused on battery electric technology. However, FCB deployment projects are also underway with the aim of potentially integrating hydrogen technology more widely into their vehicle fleets. Several of these projects include articulated fuel cell buses.

- Technical assistance for the deployment of eight fuel cell articulated bus with the BHNS line in Pau since 2019.
- Le Mans deployment project[39] of ten fuel cell articulated buses.
- Metz deployment project[40] of ten 18-meter fuel cell bus.

Overall, despite the relatively low share FCBs represent in the overall bus fleet in France, it is important to highlight that articulated buses are already a reality and have been in operation since 2019 with the first model being deployed in Pau. The map below, created by France Hydrogène Mobilité with the support of ERM, illustrates the status of announced hydrogen bus deployment projects in France, differentiating between standard and articulated models.



39 Actu.fr (28 May 2022). Le Mans: the city's buses will run on hydrogen as early as 2024
40 France Bleu (18 October 2021). Metz: a project to run green hydrogen-powered buses as early as 2025

Figure 9: Overview of fuel cell bus deployment projects announced in France (France Hydrogène Mobilité).

In conclusion, while hydrogen technology is just starting to be part of PTOs' and PTAs' fleet strategies in France, its future deployment holds promising potential, and small-scale deployments are multiplying across the country. As will be highlighted further below, this will also depend on the development of other key components of a successful hydrogen ecosystem, such as a reliable hydrogen refuelling infrastructure network.

Spain Cluster

Approximately 61,000 buses and coaches are deployed across Spain as of 2022[41]. With regards to urban and interurban buses (excluding coaches), more than 12,000 were deployed across 21 metropolitan areas of Spain as of 2021[42]. On average, articulated buses represent only 11% of the bus fleet. However, the share can vary significantly from one area to another. For instance, in Pamplona, 38% of the 159 urban buses were articulated buses in 2021 whereas in Madrid out of the 1,134 urban buses registered in 2021, only 86 were articulated, representing less than 4% of the fleet.

As for other countries across the European Union, the decarbonisation of public transport is accelerating. As of 2022, natural gas is the leading low-emission technology deployed with 6%[43] of the Spanish fleet having transitioned to it. Battery electric buses only represented a small percentage of the fleet in 2022 with 0.7%[44]; however, announcements have been made since that time. with regards to BEB orders or deployment plans across the country. As of early 2024, fuel cell technology represents only a very small fraction of the bus fleet across Spain. Compared to most of the other European countries and regions previously presented, Spain's journey with regards to introducing hydrogen within its mobility strategies has been very recent and began in Barcelona, Spain's second-largest metropolitan area.

Transports Metropolitans de Barcelona (TMB) operates under the Àrea Metropolitana de Barcelona (AMB), which manages the bus services in Barcelona. TMB owns and operates its fleet of buses while also purchasing buses for other operators within the AMB jurisdiction. Currently, TMB owns approximately 1,100 buses, and additionally purchases 800 buses for other operators. The composition of TMB's low-emission bus fleet includes 318 CNG buses, 115 battery electric buses, and 8 hydrogen buses. The operator targets achieving a clean fleet by 2030, aiming to eliminate all diesel vehicles and replace them with hydrogen and electric buses.

TMB's journey with hydrogen started in 2020 with the announcement that the procurements of 8 fuel cell uses was awarded to the Portuguese OEM, Caetano Bus. These buses were procured under the JIVE 2 project. In 2020 as well, TMB selected Iberdrola to build Spain's first public green hydrogen production and refuelling station. In January 2022, the first refuellings were carried out and operations began for the 8 fuel cell buses.

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[41] ACEA (February 2024) Vehicles on European Roads

[42] Ministry of Transport and Sustainable Mobility (Spain). (2022) Number of vehicles by metropolitan areas, type of bus and environment. The considered metropolitan areas are Madrid, Barcelona, Valencia, Sevilla, Asturias, Málaga, Mallorca, Bahía de Cádiz, Zaragoza, Gipuzkoa, Camp de Tarragona, Granada, Almería, Alicante, Valladolid, Lleida, Pamplona, A Coruña, Jaén, León, Cáceres.

[43] ACEA (February 2024) Vehicles on European Roads

[44] ACEA (February 2024) Vehicles on European Roads

TMB's operations are quite intensive, with the buses being put into service for 18 hours a day, leaving limited opportunities for charging. Consequently, hydrogen buses provide a viable alternative to battery electric buses, especially for longer routes where extended range and quick refuelling are critical. In addition, TMB acknowledges the operational challenges battery electric buses face, especially during the summer months when air conditioning significantly impacts the vehicle's range. As a result, the operator envisions hydrogen buses playing a crucial role in Spanish public transport, especially as Spain's abundant wind and solar resources position it well for cost-effective hydrogen production. TMB is already preparing for this transition at a larger scale as by the end of 2024, the operator will have received an additional 36 standard 12-meter fuel cell buses as well as Spain's two first articulated fuel cell buses. The long-term objective is for these buses to replace battery electric articulated buses and to increase the number of hydrogen buses operating in the city to 62 by 2026. Articulated buses are particularly effective in Barcelona due to the city's vertical and horizontal street layout, which reduces the need for frequent turning.

Following Barcelona, another major Spanish city has recently announced the procurement of fuel cell buses: Madrid.

Empresa Municipal de Transportes de Madrid (EMT) is the public transport operator owned by the Madrid City Council. EMT operates over 2,100 buses, one of the largest fleets across Europe. Out of those 2,100 urban buses, less than 100 are articulated, representing less than 5%. These buses are primarily used to accommodate a larger number of passengers on routes with high passenger volumes. Nevertheless, the operator plans to transition to route plans with higher bus frequencies (every 10 minutes) which would make articulated buses a less efficient option due to the risk of low occupancy rates.

With regards to the decarbonisation plan of EMT Madrid, an ambitious plan was detailed in the company's Strategic Planning for 2021-2025[45], aiming to have an 100% clean-energy vehicle fleet which they have already achieved. The buses operated today in Madrid are all battery electric or fuelled by natural gas. All the articulated buses were transitioned to CNG as part of this strategy. In Q1 2023, EMT Madrid ordered its first 10 H2.City Gold 12-meter bus from CaetanoBus which began to be delivered in Q3 2024.

Table 2: Evolution of the composition of the EMT's bus fleet at the end of each year as per the Strategic Plan for 2021-2025

Fuel type	2020	2021	2022	2023	2024	2025	2026	2027
Diesel	388	176						
CNG	1552	1678	1829	1744	1661	1561	1451	1351
Hybrid	47	47	17	17				
Hydrogen				10	10	10	20	20
Battery Electric	81	179	254	329	429	529	629	729
TOTAL	2068	2080	2100	2100	2100	2100	2100	2100
% fleet electrified	3.9%	8.6%	12.1%	16.1%	20.9%	25.7%	30.9%	35.7%

As reflected in the Strategic Plan, EMT plans to continue incorporating electric buses into its fleet as they are well-suited for city service due to their improved autonomy and convenience of overnight charging at the depot, requiring only one charge per day. On the other hand, EMT has uncertainty regarding the

[45] EMT Madrid (December 2021). Strategic Plan for Empresa Municipal de Transportes de Madrid (2021 – 2025).

expansion of hydrogen buses. The decision on hydrogen buses will depend on policy considerations and their impact on future procurement. Despite the challenges that may arise when adopting a new technology, EMT recognised that for longer routes extending beyond the range of electric buses, hydrogen buses remain necessary due to their greater range and faster refuelling capabilities.

Beyond these two cities, the development of fuel cell buses in the Spanish public transportation landscape is very slow despite growing momentum around hydrogen production projects, reflected for instance through the H2Med project which aims to connect the hydrogen networks of the Iberian Peninsula with the North West European networks[46].

2.3 Overview of the hydrogen fuel cell articulated bus offers in Europe

2.3.1 Available and upcoming fuel cell articulated buses offers

Over the past decade, the market for fuel cell buses has been developing, with existing original equipment manufacturers (OEMs) as well as new joiners entering the market and developing their portfolio. After a first focus on standard buses, the fuel cell articulated bus offer is now expanding. Several European manufacturers are developing an offer for articulated models: amongst the historical leaders in the European bus market, Mercedes has been developing articulated buses. Solaris, CaetanoBus and Van Hool[47], among the smaller national OEMs, entered the bus fuel cell market as a new market, and SAFRA as a pure player entering the bus market with a zero-emission only offer.

The table below lists the main models available/in development on the market, as well as their main characteristics.

Table 3: Available and under development fuel cell articulated bus offers

OEM	Nationality	Fuel cell standard bus offer available	Articulated bus model	Development level	Fuel cell power (kW)	Battery capacity (kWh)	Range announced (km)	Passenger capacity	Commercialisation date
Solaris	Poland	Yes	Urbino 18 hydrogen[48]	Commercialised	100	60	350	140	2023
Mercedes (Daimler)	Germany	Yes	eCitaro G fuel cell (3 or 4 doors)[49]	Commercialised	60	min. 295	500	128	2023
SAFRA	France	Yes	HYCITY H2 18[50]	Under development	*N/A*	*N/A*	*N/A*	*N/A*	2024/2025
CaetanoBus	Portugal	Yes	H2City Gold 18 m[51]	Under development	*N/A*	*N/A*	*N/A*	*N/A*	2025
Arthur Bus	Poland	No	ARTHUR H2 BUS 18[52]	Under development	60 - 125	45	400	138	2025
Van Hool[53]	Belgium	*Yes*	*Exqui.City18*	*Commercialised*	*N/A*	*132*	*300*	*46*	*2019*

[46] H2med Project
[48] Solaris – Hydrogen
[49] Mercedes-Benz Bus – Hydrogen
[50] H2Mobile (9 October 2023). Hydrogen bus: the SAFRA HyCity makes its Busworld debut and interview with SAFRA (November 2023).

Van Hool	Belgium	*Yes*	*A18 fuel cell*	*Commercialised*	*100*	*132*	*N/A*	*51*	*N/A*

The following section will provide more insights into each OEM's offer for fuel cell buses.

- Solaris

Solaris is the leader in zero-emission bus (FCB and BEB) market shares in Europe. Between 2012 and 2023, Solaris's zero-emission bus aggregated market shares in Europe was 14.5%, positioning them as number 1 ZEB manufacturer[54]. Solaris's FCB offer started in 2021 with the Urbino 12 hydrogen, their first 12m fuel cell hydrogen model commercialised in Europe.

In 2022, Solaris presented its first 18-meter articulated hydrogen bus model: the Urbino 18 hydrogen. The buses are not yet in operation, but orders have been placed across Europe and deliveries are expected in 2024. The first order was reported in February 2023 by the German transport company Stadtwerke Aschaffenburg Verkehrs GmbH (2 buses)[55]. More recently, in April 2024, Solaris announced that the public transport operator in Frankfurt am Main (In-der-City-Bus GmbH) placed an order for 9 Urbino 18 hydrogen buses which are expected to be delivered in July 2025[56].

- Mercedes-Benz Bus

Mercedes-Benz is a legacy bus OEM, having started its activities in 1985. In 1997, the first fuel cell bus was unveiled: the NEBUS. Today, this model no longer exists but Mercedes-Benz offers two new fuel cell bus model under the eCitaro brand: the eCitaro fuel cell and the eCitaro G fuel cell bus, both fuel cell range extender buses, the former measuring ~12m bus and the latter ~18m. The 12m model was officially launched in June 2023, during the Global Public Transport Summit of UITP (Union Internationale des Transports Publics) and its articulated version was showcased in March 2024 at Mobility Move in Berlin. The first three series production models were ordered in 2022 and delivered to the Rhein-Neckar Verkehr GmbH in Heidelberg in November 2023. Another 45 buses are expected to be delivered by the end of 2025 to the same operator[57]. Mercedes-Benz was awarded another tender in Italy by the public transport operator in Bolzano, SASA, which lead to an additional 9 eCitaro being ordered[58].

- SAFRA

[50] H2Mobile (9 October 2023). Hydrogen bus: the SAFRA HyCity makes its Busworld debut and interview with SAFRA (November 2023).
[51] CaetanoBus and Toyota Motor Europe presentation at the JIVE 2 Bus Roadshow (17 January 2023). Company and H2 bus technology overview and Interview with Caetano (May 2024).
[52] ARTHUR BUS – Company brochure
[53] In April 2024, VanHool declared bankruptcy before being acquired by VDL. The models have therefore been greyed out from the table but shown as a historical perspective on the market status up until March 2024.
[54] Solaris (12 March 2023). Solaris maintained its position as the European e-mobility leader. The company sums up 2023
[55] Sustainable Bus (17 February 2023). The first order for Solaris 18m fuel cell bus comes from Aschaffenburg (Germany)
[56] Solaris (15 April 2024). Frankfurt opts for hydrogen-powered Solaris buses for the third time – this time in articulated version
[57] Electrive (25 November 2023). Daimler Buses delivers first fuel cell eCitaro G
[58] Sustainable Bus (7 June 2023). 18-meter hydrogen buses for Bolzano: 9-units lot awarded to Mercedes

SAFRA is a French pure zero-emission bus manufacturer, having decided to focus on developing hydrogen fuelled buses since 2011. SAFRA launched its offer with the 12-meter Businova model in 2018. In 2022, SAFRA unveiled the design of its new product line, HYCITY®. This product line will include a 12-meter and an 18-meter model. The 12-meter bus was launched in 2023 and the articulated bus model is yet to be officially presented. The first prototype will be under development in 2024 and deliveries of the buses are expected for 2025 / 2026.

- CaetanoBus

Caetano is a Portuguese bus and chassis manufacturer. In 2019, they presented their first 12-meter urban fuel cell bus, the H2.City Gold. The bus started to be commercialised in 2020. The FCB portfolio of the company is expected to expand as Caetano are planning to initiate development for fuel cell articulated buses by the end of 2024[59].

- ArthurBus

ArthurBus is a young pure zero-emission bus player on the market, offering both battery electric and fuel cell buses. The company is based in Munich (Germany) with the production facility based in Lublin (Poland). As of early 2024, only a 12-meter demonstration bus is in operation and can be rented for test rides in various cities. The company portfolio is expected to expand in the near future, including an 18m articulated fuel cell model, the Arthur H2 Bus, expected for 2025[60].

- Van Hool

As previously mentioned (see footnote 47), VanHool filed for bankruptcy at the beginning of 2024. The future of the manufacturer's fuel cell bus models is uncertain at the time of writing the report. Nevertheless, given the role the OEM had in the early years of fuel cell bus deployments, some insights into their offer are provided.

Van Hool was among the pioneers in the development and commercialisation of fuel cell buses in Europe. Van Holl developed the first fuel cell electric articulated bus model to be put in service in the world, the Exqui.City18. This vehicle was first deployed in Pau, France in 2019. The 8 buses are still in operation. The Exqui.City18, as well as its 24-meter counterpart, the Exqui-City24, were developed as Bus Rapid Transit (BRT) vehicles. Van Hool later expanded its fuel cell bus portfolio with the new A-line including an articulated model: the A18 fuel cell bus.

2.3.2 OEM Strategies towards transitioning articulated buses to zero-emission vehicles

The following section will focus on the strategies and approaches of some of the OEMs yet to be involved in the articulated fuel cell bus sector as well as OEMs looking into including fuel cell bus models to their portfolio. As mentioned in the introduction, not all interviewees have agreed to be mentioned in this report. The provided information has therefore been anonymised when needed to comply with the participants' request.

At the European level, among the OEMs involved in the fuel cell bus sector, many have not yet developed a specific offer for articulated fuel cell buses. Most fuel cell bus manufacturers have begun their hydrogen journey through the development of standard buses (e.g., Iveco, Irizar, etc.), and the integration of articulated fuel cell buses has not yet been implemented in their short-term roadmaps.

[59] Information gathered during an interview with Caetano in May 2024.
[60] BusPlaner (9 April 2024). Arthur Bus: hydrogen bus at BUS2BUS and on Roadshow

Nevertheless, amongst the OEMs interviewed, several have expressed potential interest in including articulated buses in the portfolio and confirmed they believe these models would enable to complete their product offering. Some OEMs on the other hand have made the decision not to include articulated buses in their portfolio but rather focus on other specific product niches, such as minibuses. This is the case of Rampini, an Italian manufacturer.

The overall landscape of the future offer of hydrogen articulated buses changes when looked from a cluster level, also depending on the current maturity of the hydrogen market. In the Nordic cluster for instance, there are no OEMs currently offering hydrogen buses, neither 12- nor 18-meter. However, as of 2022, sales of alternative fuels and electrified vehicles for one of the interviewed bus OEMs constituted 8.3% of total sales worldwide, equivalent to 7,157 vehicles encompassing trucks and buses. With their commitment to achieving a 50% sales volume from electric solutions by 2030, a substantial market share is still available for new technologies to be introduced. For Europe, the second-largest market, an increased demand for fuel cells is essential to becoming a substantial influencer in their strategy.

The interviewed bus OEM responded to inquiries concerning the present and future representation of fuel cell buses (FCBs) in their overall sales. They envision that FCBs will constitute 20 to 30% of their total sales by the year 2035, although this technology is not yet included in their short-term offer plans. This projection, represented in the graph below, translates to an estimated production and sales volume ranging from 253 to 380 FCBs, based on answers from the questionnaire.

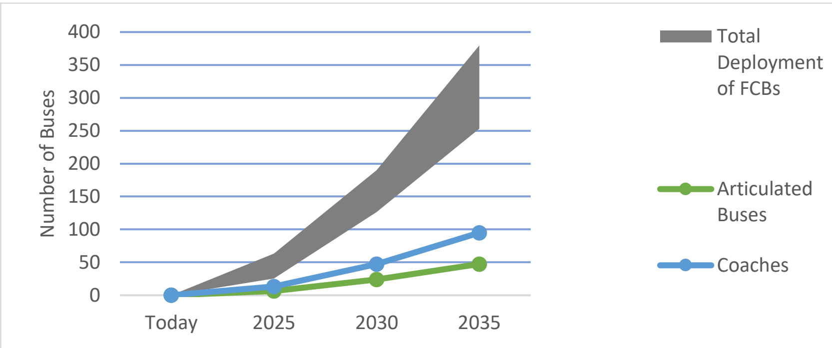

Figure 10 : Interviewed bus OEM's FCBs rate of deployment.

In addition, from desktop review, the Nordic cluster coordinator was able to confirm that other OEMs are adopting somewhat similar strategies, where hydrogen is expected to constitute an important share of offered vehicles by 2030.

In the German cluster, several OEMs already have fuel cell articulated buses in their portfolio (although in minor shares) or are planning to introduce them soon. Their zero-emission strategy is based on the simultaneous deployment battery-electric and fuel cell-electric vehicles for their conversion to zero-emission buses. For the latter, participants to the JIVE 2 questionnaires have confirmed they plan for hydrogen buses to account from 30% up to more than 50% of their offer by 2035. None of the participants to the questionnaire has included retrofitting in its hydrogen offer strategy. According to the interviewees, this is due to the excessive individualisation and issues linked with interfaces retrofitting requires for vehicles such as articulated buses.

In the Benelux region, two major OEMs are present: VDL and Van Hool, which both participated in the study. The case of VanHool has been previously addressed. Up until the takeover of VanHool by VDL, the OEM did not offer hydrogen buses in their portfolio. Since the takeover, no announcements have been made around the continuation of the urban bus line, including regarding the fuel cell bus models.

3. Coaches

3.1 Introduction

The following section will focus on coaches. Coaches can be split into two main categories: “low-entry” and “normal floor” models. Low Entry coaches are classified as Class II vehicles: these are vehicles constructed primarily to transport seated passengers, but which are designed to also allow for passengers to stand in some areas on the bus (e.g., gangway). Typically, these buses are suited for both urban operations as well as suburban and intercity travels. Normal Entry coaches are Class III vehicles: they are designed to exclusively transport seated passengers and are therefore mostly operated on suburban, intercity or cross-country routes. Overall, compared to standard urban buses (12-meter buses and even articulated buses), coaches tend to have higher yearly mileages which renders their decarbonisation more challenging.

The organisation of coach operations varies from one country to another. However, similar coach use cases can be defined: scheduled public transportation, school services, touristic operations and other occasional transportation needs.

In this section, a deep focus will be made on the French coach market, providing insights into the current coach fleet and looking at the decarbonisation options. For the other European markets, less insights will be provided due to the limited information gathered through the surveys and interviews led by the cluster coordinators responsible for their respective markets.

Lastly, an overview of the latest OEM developments and announcement on the fuel cell coach market will be provided.

3.2 Overview of the coach deployments across Europe

The following section will be largely focused on the French coach market, deep diving into the structure of this market and the regulatory landscape driving the transition to better understand the challenges this sector can phase when it comes to decarbonisation.

Small insights into other European markets are also provided, particularly looking at their interest in adopting fuel cell models.

French Cluster

In October 2023, France Hydrogène Mobilité and AVERE-France published a report (“*La transition de l’autocar vers des technologies zéro émission : quels besoins et perspectives*”), written by ERM. The following information regarding the French coach market is extracted from this report (and translated to English).

Introduction to the environmental and regulatory context of the French coach market

The French coach fleet represents twice as many vehicles as the bus fleet; yet, only around 100 zero-emission coaches were in service in France in 2023, compared with almost 1,500 zero-emission buses on the road on January 1st 2022[61].

[61] Ministries of Spatial Planning and Ecological Transition (France), (3 January 2023). 66,600 coaches and 27,900 buses on the road on January 1, 2022.

On the same date[62], 66,000 coaches were in operation in France, almost all of them powered by diesel engines (98%). As illustrated below, the main alternative to diesel deployed was the natural gas coach. Only a few battery electric coach units (fewer than 100 vehicles) were in operation.

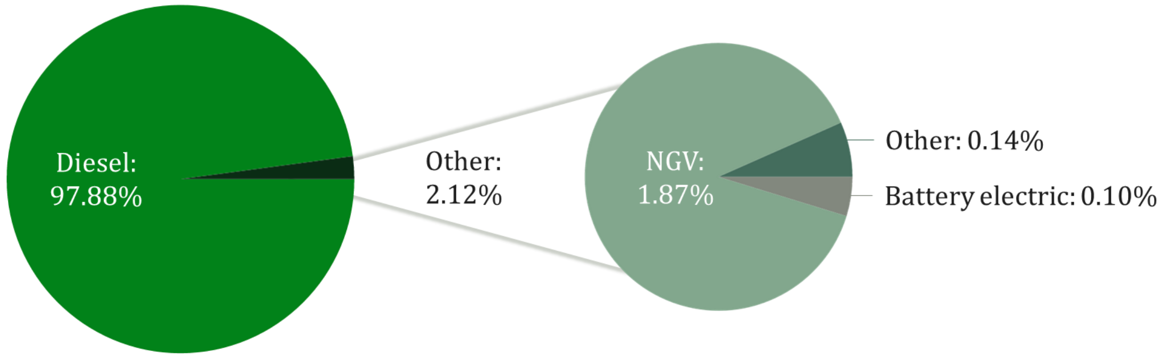

Figure 11: Distribution of the coach fleet by fuel type in France as of January 1st 2022 (Source: SDES)

The number of zero-emission coaches (battery-electric or fuel cell electric) deployed nationwide in 2022 was therefore very low. This finding is very different to what is observed in the urban bus segment, where battery electric buses represented 5% of the fleet [63], and fuel cell electric buses have developed strongly in recent years, generating announcements of deployments of several hundred vehicles[64].

This gap between the bus and coach sectors is mainly due to a regulatory context that is much more encouraging for the bus segment, partially justified by the priority given to reducing atmospheric pollutants in suburban areas. For instance, the transcription of the Clean Vehicle Directive in the French law has required local authorities in urban areas with more than 250,000 inhabitants to include 25% battery-electric or fuel cell buses in their fleet renewals since July 2022, and this proportion is supposed to rise to 50% from 2025[65]. In the coach segment, there is no regulatory obligation (as of May 2024) to deploy electric or fuel cell vehicles.

This lack of incentives in the first half of the decade has two consequences:

The demand for zero-emission coaches is low since operators are not subject to any obligation, and these solutions entail additional costs and the corresponding complexities linked to the transition.

French and European manufacturers are not necessarily prioritizing the development of zero-emission coaches, with the result that the available range of new battery-electric coaches comes mainly from Asian manufacturers, while fuel cell electric coaches are still being developed in 2023 by a limited number of players.

[62] Ministries of Spatial Planning and Ecological Transition (France), (3 January 2023). 66,600 coaches and 27,900 buses on the road on January 1, 2022.

[63] UTP (Union des Transports Publics et ferroviaires) (October 2022). Le Parc des Véhicules des Services Urbains au 1er janvier 2022 (*Urban Services Vehicle Fleet at January 1, 2022*)

[64] France Hydrogène, (2023). Mapping of hydrogen electric vehicle deployment projects in France. Based on public announcements by prime contractors and confidential projects identified by France Hydrogène, more than 600 hydrogen-powered electric buses should be deployed in the next few years.

[65] Ordonnance n° 2021-1490 November 17th 2021 on the transposition of Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.

Nevertheless, as previously highlighted, in France the coach fleet represents twice as many vehicles as the bus fleet. The transition of this vehicle segment is therefore key to achieving greenhouse gas (GHG) emission reduction targets, and in particular carbon neutrality by 2050.

Additional regulations could gradually encourage the deployment of low-emission or even zero-emission coaches: these include low-emission mobility zones (LEZ-m) and CO2 regulations for manufacturers, which could become the most powerful regulatory levers in the coach segment. However, there is no clear visibility of the French future regulatory developments at this stage.

Deep dive into the French Coach Market

Four main use cases can be identified within the coach sector in France:

- School transportation
- Regular interurban and regional routes
- Tourism
- Freely organised transport services (e.g., Flixbus and BlaBlaCar Bus).

The French coach fleet is unevenly distributed between these segments. As shown in Figure 12 below, school transport and regular lines account for the vast majority of usage (~90%), while tourist transport represents less than 10% of the fleet, and freely organized transport services 1%.

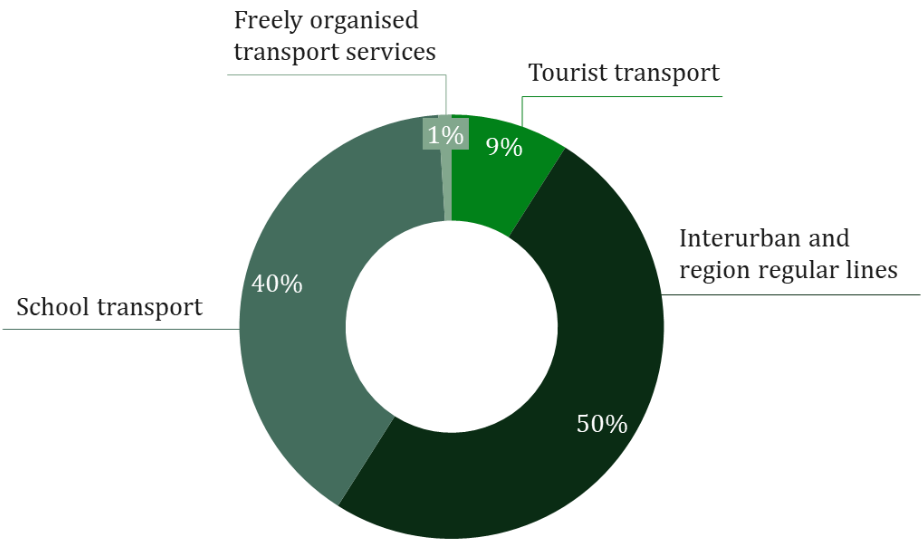

Figure 12: French Coach Fleet by Segment (Source: FNTV)

Most vehicles deployed in these segments in France are so-called "high-floor" or "normal-floor" coaches, i.e., with a floor higher than the road, and fitted with luggage compartments. These coaches are classified as Class III vehicles. "Low Entry" coaches represent just 5% of the French fleet and fall into the Class II category. They can be used for suburban transport, carrying up to 50% of standing passengers, and are similar in profile to city buses.

These four usage segments have very different operational characteristics, which are described in the following paragraphs.

- <u>School transport</u>

Daily, 2 million pupils from primary to high school travel to school by coach, 144 days a year. School transport thus accounts for almost 40% of coach transport use, with some 26,500 vehicles dedicated to school transport in 2022.

It is mainly under the authority of the Regions, which delegate its operation to transport companies under public contracts. School coaches generally make one or two rounds a day, for a daily mileage of up to 175 km/day. Annual mileage in this segment is generally between 15,000 and 30,000 km, with an average of around 25,000 km/year.

- <u>Intercity and regional scheduled services</u>

Vehicles in this segment provide transport services within the same region, or between cities in different regions. Regular intercity and regional lines account for the largest share of passenger transport by coach, and like school transport, fall under the authority of the Regions. In 2023, some 33,000 coaches were dedicated to these routes, representing around 50% of all coaches in circulation in France.

Coaches operating on these routes generally cover a higher mileage than those operating on school routes. Depending on the region, daily mileage varies from 150 to 400 km/day. Most vehicles cover between 30,000 and 60,000 km/year but can reach up to 80,000 km/year.

- <u>Tourist transport</u>

This segment is used for a wide variety of purposes, including the transport of tourist groups, sports clubs, and associations. Demand in this segment is therefore highly variable. In 2022, tourist transport accounted for some 6,000 vehicles in France, or 9% of the fleet. Unlike school transport or regular routes, this activity does not necessarily depend on a public organizing authority. Operators respond to travel requests (from travel agencies, tour operators, associations, companies, schools, etc.) provided they hold a license issued by the French Transport Regulatory Authority.

Annual mileage is generally higher than for scheduled services, since they operate over longer distances, in France or abroad. This can vary from 20,000 to 100,000 km/year. Average daily mileage varies widely depending on the activity, from 100 km to 700 km for certain intensive uses.

- <u>Freely organised services</u>

Freely organized services are the result of the opening up of national long-distance coach routes which was implemented in the law of August 6th, 2015, on growth, activity and equal economic opportunity[66]. In France, these services are organized around national and international routes, by two main operators, FlixBus and BlaBlaCar Bus, who subcontract transport to small and medium-sized road passenger transport companies. By 2023, around 500 coaches are operating in this segment.

The freely organised services are characterized by long-distance routes that can extend beyond France's borders. Vehicles can cover between 80,000 and 250,000 km/year, and up to 800 km/day. Coaches generally have several drivers on the same day to use the vehicle for as many kilometres as possible over its lifetime.

- <u>Re-use of coaches between segments</u>

[66] Ministries of Spatial Planning and Ecological Transition (France), (8 February 2017). Freely organized services.

While the segmentation proposed above gives an overall view of the passenger transport sector and the breakdown of the fleet, there is nevertheless a certain porosity between segments, enabling fleet operators to diversify their activities and reuse coaches for different transport services. In particular:

- Large-scale re-use of school transport coaches for occasional transport outside school transport hours, and outside the school year, mainly for extra-curricular activities. This may involve, for example, return trips to swimming pools or other leisure facilities, or full-day school outings (under contract with schools or town halls in particular).
- The re-use of regular line coaches for occasional transport, with the agreement of the mobility organizing authority.
- The occasional use of touring coaches on freely organized services.

Nearly 90% of the French coach fleet (school and regular services) is operated under the authority of the Regions since the transfer of responsibility for school transport to the Regions under the Law of 15th August 2015 on a new territorial organisation of the Republic (NOTRe law)[67]. As a result, the Regions now have responsibility as Mobility Organising Authorities (AOM) for inter-urban, regional and school transport within their territory. The Regions may also be required to facilitate services in the occasional segments. Understanding how regional coach management works is therefore essential for assessing the sector's ability to make the transition to zero-emission solutions.

Regions rarely own coaches. As shown in Figure 13 below, over 90% of coaches are owned by 3,000 private passenger transport or rental companies, and only 7% of the fleet is owned by an administration, local authority or public institution (often municipalities). However, the coach ownership model is changing. The Ile-de-France region, through its AOM Ile-de-France Mobilité (IDFM), owns school coaches and regular lines. This model has also been adopted by some major cities. The private sector comprises a majority of SMEs, with an average of 33 employees and operating around twenty coaches[68]. Around 55% of coaches are operated by SMEs, generally on school, tourist or SLO routes, and 45% are operated by subsidiaries of three major groups (Keolis, Transdev and RATP Dev).

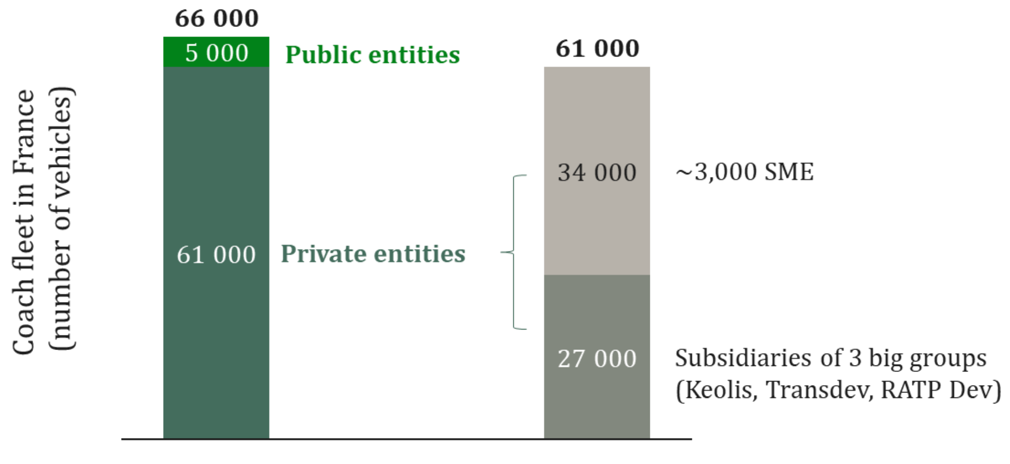

Figure 13: Breakdown of the coach fleet between public entities and private companies (SMEs and large groups) in France (Source: FNTV)

[67] Ministries of Spatial Planning and Ecological Transition (France), (5 September 2022). Law on the new territorial organisation of the Republic (NOTRe)

[68] Avere-France, (21 September 2021). Avere-France publishes its electric bus guide to support local authorities and professionals in the energy transition of their

The Transport Code[69] provides for agreements between the Organising Authorities for Mobility (AOM) and transport operators. However, the terms of this agreement are not imposed: the duration of contracts can vary between 1 and 10 years, and the AOM can entrust the transport activity via a public contract or a public service delegation. The major difference between these two operating methods lies in the revenue received by the operator:

- Under a public contract, the operator provides a service that is precisely defined by a set of specifications, with limited room for manoeuvre. The remuneration is defined in advance and is independent of the number of passengers on the routes: the AOM receives the operating revenue and bears the risk of the number of passengers on the routes. In most cases, school transport takes the form of a simplified one-year public contract, renewable up to 3 times.
- Under a concession or public service contract, the operator is involved in managing the service. The operator bears the operating risk, since its remuneration depends in part on the revenue generated by the operations. Public service contracts are generally signed for periods of 5 to 8 years, which gives more time to make the assets deployed profitable. Most scheduled services are operated under public-private partnerships.

In both cases, the AOM rarely owns the vehicle (with exceptions such as IDFM) but sets out its expectations in the call for tenders: the duration of the contract, technical expectations (average or maximum age of vehicles, Euro VI, capacity, etc.), economic and environmental expectations. An AOM with an ambitious transition strategy can therefore encourage the deployment of zero-emission solutions by including these criteria in its call for tenders when renewing contracts.

Other European Markets

Beyond the in-depth analysis focused on the French coach market, some insights from other markets were collected through the interviews and questionnaires.

In the Nordic countries, coaches are primarily utilised for inter-city or regional routes, with a focus on higher distances and medium-low frequencies. Within the organisations reached during the JIVE 2 study, 7 out of 11 already manage coaches, and they represent on average 46% of their total fleets (i.e., approximately 950 vehicles in total).

Based on the results from the survey, the graph below (Figure 14) represents the current level of acceptance of the different low- and zero-emission technologies for coaches and thus provides an overview of the trends that can be observed in the cluster. Across the respondents, biofuels represent the preferred alternative fuel for coaches, followed by battery electric coaches and natural gas-fuelled buses. Hydrogen fuel cell and hydrogen ICE vehicles currently remain a limited option for the coach sector for the participants to the survey, despite the emphasis on the transition to zero-emission technologies in the cluster. However, this could change, with around 40% of organizations surveyed expressing an interest in trialling fuel cell coaches for further integration into their fleets, recognising their advantages in long distance transport.

Still, estimation for future demand of hydrogen coaches remains limited, and the results from the questionnaires have low reliability. This comes from an upfront uncertainty about future demand for coach vehicles in general, regardless of the GHG reduction technology of choice. In addition, PTAs in the region apply to coaches the same strategy described for articulated buses, requiring zero-emission vehicles in their current tenders, but abstaining from recommending any particular technology. This

[69] Transport Code - Légifrance - 2023

could support the short-term deployment of BEBs ahead of fuel cell vehicles, therefore rendering predictions on future demand even more challenging.

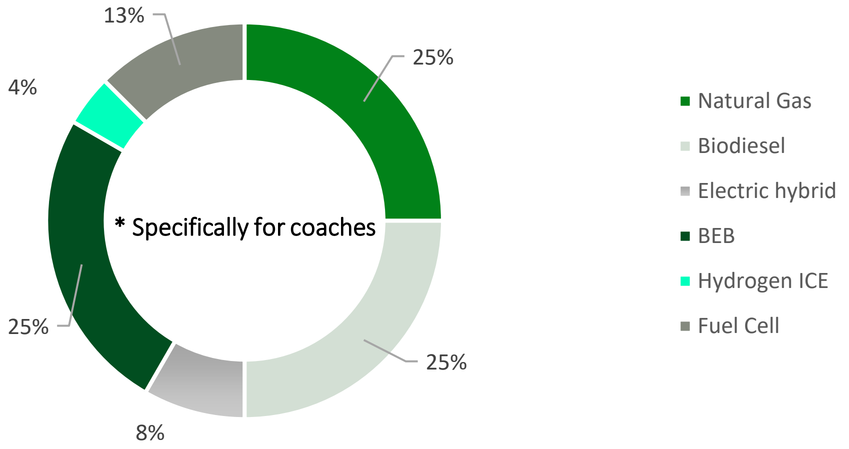

Figure 14 : The current level of acceptance of ZE technologies in the Nordic cluster (as per the responses to the survey).[70]

Among the German surveyed bus operators, only 3 are currently operating coaches, mostly on inner-city routes, and own their respective fleets. The number of coaches operated by these organizations varies between 5 and 116 units, representing between 20 and 100% of their fleets. None of the three operators currently operate fuel cell coaches in their fleet, nor do they intend to procure any in 2024. This is likely linked to the fact that none of the operators are expecting their coach fleets to increase significantly in the next years, therefore limiting the demand for new zero-emission vehicles.

Nevertheless, two of these operators express keen interest in integrating fuel cell technology into their long-term strategies, with one even envisioning a complete fleet conversion. However, the limited availability of fuel cell coach models on the market poses a significant hurdle to this transition. This factor has indeed been mentioned as a further obstacle to the deployment of fuel cell coaches, alongside high CAPEX and OPEX costs, and low availability of refuelling and maintenance infrastructures.

No further information regarding the Benelux and Spanish market was provided due to limited access to the information by the cluster coordinator.

3.3 Overview of the fuel cell hydrogen coach existing and upcoming offers in Europe

As previously mentioned, in October 2023, France Hydrogène Mobilité and AVERE-France published a report ("*La transition de l'autocar vers des technologies zéro émission : quels besoins et perspectives*"), written by ERM. The report provided a thorough overview of the fuel cell coach offering. The following information regarding the coach offering is extracted in large part from this report with the addition of recent updates.

As described in detail in the French coach fleet overview, diesel coaches represent 98% of the market. This is a trend that can be seen across European countries. In France, only a few zero-emission models

[70] Graph based on the on the 17 responses received from PTAs/PTOs by the Nordic cluster to the questionnaire, Autumn 2023.

were in operation in January 2022, all of which were battery electric coaches. The European fuel cell hydrogen coach market is still very nascent, with the first fuel cell coaches expected to begin operations in 2024. Two European projects, HyFleet (supported by FlixBus) and CoacHyfied, were undertaken with the aim to develop hydrogen-powered electric coaches. Moreover, a few OEMs have announced the ongoing development of this type of vehicle, including Turkish manufacturer Otokar (as part of the European CoacHyfied project), as well as Portuguese and Turkish players CaetanoBus and TEMSA, which are joining forces. However, there are still few initiatives to market mass-produced hydrogen electric coaches in France and Europe. As with battery-electric technology, this time lag with buses is mainly due to the regulatory gap between the two segments. Against this backdrop, several French players are positioning themselves to develop retrofit solutions in order to accelerate the deployment of this solution, which is essential to the complete decarbonisation of the coach segment. This positioning is being driven by the French regions, which are keen to accelerate their decarbonisation drive despite the absence of regulatory obligations. In Normandy, the Occitanie Region and Auvergne-Rhône-Alpes, the first fuel cell electric coaches should be deployed from 2024, driven by regional players such as SAFRA and GCK.

The main fuel cell electric coaches being developed for the European market are listed in the table below (non-exhaustive list)[71].

Table 4: Overview of the European fuel cell coach offers commercialised and under development (all information comes from the France Hydrogène Mobility report; inputs with an asterisk has been updated since the publication or is new)

OEM and Bus Model	Nationality	New or retrofit	Coach Type(s)	Development level	H2 tank size and pressure	Fuel cell capacity (kW)	Battery capacity (kWh)	Range announced (km)	# of seats	Commercialisation date
GCK, IVECO Crossway LE	France	Retrofit	Low Floor	Homologation approved*	25kg @700 bar	150kW	94kWh	300km	Unchanged	2023
GCK, IVECO Crossway	France	Retrofit	Normal Floor	Homologation approved*	34-50kg @700 bar	75kW	47kWh	300 to 500km	Unchanged	2023
SAFRA, Mercedes Intouro	France	Retrofit	Normal Floor	Homologation approved*	35kg @350 bar	70kW	71kWh	Up to 500km	NA	2023
Caetano x TEMSA	Portugal x Turkey	New	Normal Floor	Under development[72]	NA	NA	NA	Up to 1,000km	NA	From 2024
Irizar	Spain	New	Normal Floor	Under development[73]	NA	NA	NA	Up to 1,000km	NA	From 2024
Wrightbus[74]*	UK	New	Normal Floor	Under development	NA	NA	NA	NA	NA	2026

[71] The information comes from the France Hydrogène Mobilité and AVERE-France report published in October 2023 and written by ERM ("*La transition de l'autocar vers des technologies zéro émission : quels besoins et perspectives*"). Updates have been made to the information based on the updates up to May 2024.
[72] Model presented at Busworld 2023 – CaetanoBus x Temsa
[73] Model presented at Busworld 2023 - Irizar
[74] Bus and Coach Buyer, (22 February 2024). Wrightbus announcement on the arrival of a fuel cell hydrogen bus in 2026 (Wrightbus – CoacH2 – Next generation hydrogen fuel-cell coach powertrain demonstrator)

Otokar Territo H2	Turkey	New	Normal Floor	Under development	60 kg @700 bar	100kW	140kWh	575km	49	2024
Nomad CAR H2 IVECO Crossway[75]	France	Retrofit	Normal Floor	Homologation approved*	50kg @350 bar	NA	NA	450km	Unchanged	2023 - 2024

The below section provides further details on some of the models mentioned in Table 4.

Caetano x TEMSA:

The OEMs CaetanoBus (Portugal) and TEMSA (Turkey) announced in September 2023 their partnership to develop a long-distance hydrogen-powered electric coach. The first model will be based on the electric version of the TEMSA HD12 vehicle (2 axles). The manufacturers have announced a vehicle range of up to 1,000 km, enabling it to meet the operational needs of long-distance cross-country travel. According to initial press releases, this coach should be launched on the market from 2024, with series production from 2025. A 3-axle version is also under development. This is a logical next step in the development of the hydrogen offering from CaetanoBus, which has already marketed its hydrogen-powered electric bus in Europe (the H2 City Gold) and is expanding its offer with articulated models as well.

GCK and the retrofitted IVECO Crossway

GCK Mobility is a company based in the Auvergne-Rhône-Alpes region of France, specialising in the conversion of all types of vehicles to battery and hydrogen electric power (road vehicles: coaches, buses, vans, trucks - off-road: snow groomers, agricultural machinery, site equipment - marine: yachts, cruise ships). In the coach segment, GCK Mobility has opted for a hydrogen-powered electric solution to meet the operational constraints of the majority of the fleet on the road.

GCK is offering to retrofit two types of coach:

- The Iveco Crossway high-floor model
- The Iveco Crossway low-floor model.

The coaches will be equipped with components developed mainly by French companies: Symbio fuel cells, Forvia tanks and GCK batteries. The high-floor version of the vehicle will offer three range options, depending on the number of hydrogen tanks on board: 300 km with an unchanged cargo hold capacity, 400 km if one cargo hold is closed off to allow additional tanks to be added, and 500 km if two cargo holds are closed off. With a hydrogen storage capacity of 34 kg, the vehicle's range is claimed to be 400 km, for a maximum speed, payload and maximum gradient identical to the original internal combustion model, regardless of weather conditions. These characteristics mean that it can be used on routes that are particularly demanding in operational terms, especially in mountainous areas.

[75] The NOMAD Car Hydrogen project, initiated by the Normandie Region and Transdev, was launched in the Normandy region to develop a retrofitted hydrogen coach to be deployed in commercial use on a regional line. The bus is therefore not currently produced for purchase.

The vehicle in its high-floor configuration has already undergone road tests, and in February 2024 GCK announced that the vehicle had successfully passed the homologation tests. This enables GCK to launch its series production, with already more than 100 vehicles on contract with several customers[76].

GCK's retrofit capacity (all vehicles combined) will be around one hundred vehicles a year from 2024, with production centralised in Clermont-Ferrand. The plant's production capacity will be tripled by working 3 shifts. At the same time, GCK plans to roll out several decentralised production plants, each with a capacity of 50 vehicles a year. As a result, almost 1,000 vehicles (all segments combined) could be produced each year by 2030.

SAFRA and the retrofitted Mercedes Intouro coaches

Retrofit kit developed by SAFRA: SAFRA is a French company with a long history in the renovation of passenger transport equipment, and a pioneer in hydrogen mobility. SAFRA has developed and marketed two standard electric hydrogen buses, the Businova and the HYCITY. In order to extend its hydrogen range to the coach segment, SAFRA is developing the H2-PACK® retrofit kit, aimed at converting thermal coaches from electric to hydrogen. This solution has been developed for the conversion of Mercedes Intouro coaches, which are widely used in France.

The retrofit kit developed by SAFRA comprises the following equipment:

- A 70 kW Plastic Omnium fuel cell system
- Six 35 kgH2 storage tanks at 350-bar developed by Plastic Omnium
- A 71 kWh Microvast battery pack
- A 350 kW Dana TM4 powertrain.

Installation of this H2-PACK kit includes:

- Removal of the combustion engine and fuel tanks
- Fitting a new energy chain, in compliance with regulatory constraints
- Connection to the existing drive train
- Integration of new ECUs and software
- Interfacing with existing equipment
- Approval of the conversions in accordance with the technical and administrative provisions of the retrofit order of 13 March 2020.

By the summer of 2023, the design phase of the retrofitted vehicle has been completed, the operational safety studies have been carried out, and the homologation phase has begun. In March 2024, SAFRA announced that their coach retrofit kit H2-PACK® designed for the Mercedes Intouro had passed all approval procedures enabling the buses to soon be put into operation[77]. SAFRA is now able to carry out the hydrogen retrofit of the first series of vehicles in industrial mode.

At the same time, SAFRA is developing a technical and after-sales partner network, in order to duplicate and accelerate the deployment of its solution. Retrofitting a coach also requires the installation of a hydrogen refuelling station in a strategic geographical location, close to the coach depot for example.

To ensure coverage of the entire value chain, the coaches retrofitted by SAFRA will be deployed as part of ecosystem projects, including both hydrogen production and distribution infrastructures and

[76] GCK, (24 February 2024). GCK obtains the world's first homologation for a retrofitted hydrogen coach for mass production

[77] SAFRA, (28 March 2024). Homologation of the coach retrofit kit, H2-PACK®

maintenance networks. The first retrofitted vehicles are part of the Corridor H2 project, supported by the Occitanie Region. SAFRA will be retrofitting 15 intercity coaches owned by the Occitanie Region. The coaches will be operated by a local public company 67%-owned by the Region. The vehicles selected for the retrofit are Mercedes Intouro EURO Vs, 10 years old and with less than 500,000 km on the clock. The Region plans to deploy these hydrogen-powered electric coaches from 2024, on regular routes: overall, this represents a potential of 1,000 coaches, spread over 360 routes, and capable of travelling up to 90,000 km/year.

Otokar Territo H2 and the CoacHyfied project

Project overview: The CoacHyfied project aims to deploy the first fuel cell electric coaches in Europe and was selected for funding by the Clean Hydrogen Partnership. The aim of the project is to encourage the development of a commercial range of hydrogen-powered electric coaches in France and Europe, by working on the following two main areas:

- Carrying out a market study to analyse the needs of coach operators in Europe, with a view to developing a suitable offer.
- The design and deployment of prototypes of new or retrofitted hydrogen electric coaches, in order to obtain technical, operational and economic feedback.
- In particular, the project will enable the deployment of 3 new hydrogen electric coaches in France by the end of 2024 - early 2025.

Key players involved

The project involves players across the entire value chain, from the suppliers of hydrogen components to the vehicle manufacturers, energy suppliers and operators.

The 3 new coaches deployed in France will be designed and produced by the Turkish manufacturer Otokar.

- They will be purchased by a regional authority, which will operate them on regional routes.
- The coaches will refuel at a public hydrogen station, which will also supply hydrogen buses deployed as part of the European JIVE project.
- Maintenance will be carried out in France by Otokar.

Main characteristics of the routes on which the vehicles will be deployed: ENGIE Solutions is working with the Region involved to identify relevant coach routes for the deployment of hydrogen vehicles. The route and coach operators have not yet been firmly selected, but it will be an inter-regional or long-distance route. The vehicles will have a mileage of between 55,000 and 65,000 km per year (as defined in the response to the European call for projects).

Technical characteristics of the vehicles: Otokar is developing a hydrogen-powered electric coach based on its TERRITO model. The vehicle will have a range of up to 575 km and will be powered by a 100kW fuel cell and a 60 kg hydrogen storage system. The coaches are currently in the design phase (design, rollover test simulations, energy simulations with air conditioning requirements and gradients, etc.). Following this design stage, the vehicles will be built, approved and delivered to the Region in late 2024 - early 2025.

4. Clusters with specific characteristics

The two clusters below (the United Kingdom and Central and Eastern Europe) have been studied differently due to their overall different bus market landscape and diversity of markets respectively.

4.1 United Kingdom cluster

The UK has been addressed separately as it has the particularity of having little to no articulated buses deployed and therefore, fuel cell articulated buses are of limited relevance. Nevertheless, the high-capacity public transport is not left unaddressed as the UK is known for its high percentage of double decker buses deployed.

The UK Department for Transport has consulted twice in 2021 and in 2022 on ending the sale of new, non-zero-emission buses suggesting dates between 2025 and 2032. For coaches, this date is expected to be around 2040[78]. A decision has not yet been communicated. Nevertheless, targets have been set by the Mayoral Authorities in England with most planning for a full fleet decarbonisation by 2040 latest, with some targeting 2030. Additionally, the UK Government has supported the uptake of zero-emission buses through various funding schemes, such as the Low Emission Bus Scheme, the Ultra Low Emission Bus Scheme or the Zero Emission Bus Regional Areas (ZEBRA). Given the upcoming elections in the UK (July 2024), the future regarding capital support for zero-emission buses is uncertain. The UK Infrastructure Bank is however increasing its support. Lastly, zero-emission buses also benefit from favourable revenue support rates where services are operated commercially through for instance the Bus Service Operators Grant (BSOG) in England[79].

As of March 2023, approximately 41,500 buses were deployed by local operators in Great Britain among which around 34,800 where single and double deck buses[80]. Thus far, the zero-emission transition of the bus fleets has been driven by battery electric buses, representing around 4.9% of the buses used by local operators. Fuel cell buses have been integrated in several bus fleets across the UK over the past years but only represent 0.2% of the overall fleet as of March 2023. The majority of these buses are deployed under the JIVE (65) and JIVE 2 (54) frameworks and among these 80% are double deck buses.

[78] Department for Transport (UK), (March 2022). Ending UK sales of new, non-zero emission buses and calls for evidence on coaches and minibuses – Consultation
[79] Department for Transport (UK), (February 2024). Bus Service Operators Grant: guidance for community transport operators
[80] Department for Transport (UK), Vehicles operated by local bus operators (BUS06)

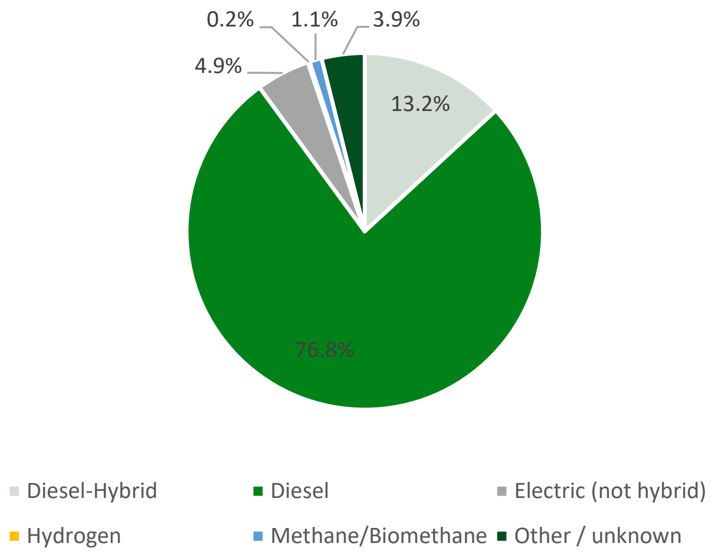

Figure 15: Distribution of buses used by local operators in Great Britain by fuel type

The UK has historically deployed double-decker buses for public transportation. These have been mostly used in high density population areas where they provide larger capacity but have also been used in private coach services throughout the UK. Alongside double-decker buses, prior to 2009, there were around 500 articulated (known colloquially as 'bendy') buses in the UK, with the majority located in London to enable public transport to better deal with large passenger volumes. However, since 2009, Transport for London (TfL) undertook a strategic decision to deploy double-decker buses as the main solution for large capacity public transport. These started to replace the articulated buses in London, starting with bus route 38 as a trial. The trial was deemed successful through passenger and driver feedback and operational data collected from the buses. The progressive rollout of double-decker buses in London continued until late 2011, replacing all of the previously deployed articulated buses.

There are several benefits that double-decker buses offer in the UK context that have influenced this change.

TfL reported having major issues with fare evasion on the routes operated by articulated buses. Deployment of double-decker buses was seen as a solution to reduce fare evasion thanks to the architecture of double-decker buses i.e., passengers are only able to board the bus from the front, passing by the driver to purchase their tickets. The shorter length of a typical double-decker bus also allows the driver to better view the entire length of the bus and ensure all passengers boarding the bus are scanning a ticket. In longer, articulated buses passengers were able to board through the rear doors without paying, and the driver could struggle to see it.

Manoeuvrability of buses is critical in dense urban areas such as London where the road topography naturally benefits shorter buses. The longer articulated buses often struggled to navigate the city streets smoothly and several routes faced recurring issues of buses unable to negotiate sharp turns, causing delays and dissatisfaction.

Capacity of modern double-decker buses is similar to that of articulated buses, hence making them a good replacement for the articulated buses. This makes them well suited for high-capacity routes in London and other major cities.

Currently, few articulated buses remain in the UK. These are typically deployed in airports where large capacity of passengers is found. Articulated buses are especially beneficial in this application due to the required quick boarding and deboarding times needed - the multiple doors allow this to happen faster than it would in a double decker bus where congestion with the stairs often occurs. Furthermore, the issues mentioned above related to fare evasion are not applicable in this specific application as there are no fares that passengers need to pay. The absence of space constraints in airports, which typically boast vast areas for the buses to manoeuvre in, means they have no major barriers in these applications.

For the above stated reasons, the UK is expected to maintain a focus on double-decker buses for most passenger applications, other than transport within airports. In the context of the JIVE II project, this means that the potential for deployment of articulated buses in the UK is minimal.

As previously mentioned, fuel cell double-decker buses are a reality in the UK and are part of several public transport authorities and operators' plans to decarbonise their bus fleets. The *Table 4*Table 5**Error! Reference source not found.** below shows the current, as of January 2024, hydrogen bus fleets, by operator, in the UK.

Table 5: List of operational UK hydrogen bus fleets, January 2024

City (Country)	Fleet operator	FC bus model	Bus type	Number of FCBs deployed (01/2024)
Liverpool (England)	Arriva Mereyside	ADL Enviro400FCEV	Double-decker bus	20
Aberdeen (Scotland)	Frist Aberdeen	Wright StreetDeck Hydroliner	Double-decker bus	25
Belfast (Northern Ireland)	Translink Metro	Wright StreetDeck Hydroliner	Double-decker bus	23
London (England)	Metroline Travel	Wright StreetDeck Hydroliner	Double-decker bus	20
Birmingham (England)	National Express West Midlands	Wright StreetDeck Hydroliner	Double-decker bus	20
Crawley (England)	Metrobus	Wright GB Kite Hydroliner	Single decker bus	15

Given the specific market context, UK bus manufacturers have developed their fuel cell offers to meet the requirements of local bus operators in this specific higher-capacity transportation market. Below are descriptions of the different hydrogen double-decker buses models that are currently available on the UK market.

Table 6: List of fuel cell double deck bus models offered by UK OEMs

OEMs	Nationality	Bus model	Development level	Fuel cell output power (kW)	Battery capacity (kWh)	Range announced (km)	Number of seats	Commercialisation date
Wrightbus	UK	Streetdeck Hydroliner FCEV[81]	Commercialised	85	27.4	450	86	2019 / 2020
Alexander Dennis	UK	Enviro400FC EV[82]	Commercialised	45 or 60	30	>480	83	2021

Wrightbus: Wrightbus is the largest hydrogen fuel cell bus manufacturer in the UK, and the first to commercially produce and deploy a double-decker model. The StreetDeck Hydroliner model has been developed as part of the JIVE project funded by the European Union.

Alexander Dennis (ADL): ADL is one of the major bus manufacturers in the UK, providing both traditional bus models as well as a range of electric buses. The Enviro400FCEV double decker hydrogen-fuel cell bus was first announced in 2022 and has since been deployed in small numbers.

4.2 Central and Eastern Europe cluster

Central and Eastern Europe represents another particular cluster, where findings included in this report are based on desktop research as well as from outcomes from the JIVE 2 Roadshows organised in the region between 2022 and 2024. The countries included in this cluster have not been directly involved in the JIVE and JIVE 2 projects, mainly due to obstacles encountered in the set-up process of the project linked to political support, especially on the financial side.

The adoption of hydrogen technology is still very nascent in this region and few deployment projects have been implemented compared to the rest of Europe. In the framework of this study, this cluster showed a lower participation level to the questionnaires, as PTAs and PTOs in the cluster are just starting to test the new technology and are not yet in the position to provide insights on specific vehicle categories such as articulated buses and coaches. Nevertheless, changes and an increased interest has been observed in the region over the past years. The JIVE 2 Roadshows have been able to contribute to driving this growth by enabling various countries to test the technology and engage with stakeholders already involved in hydrogen deployment projects.

Local public road transport is generally managed by local authorities at the city level, and many PTOs operate across the cluster. However, the operation area of the PTOs and the competition level between PTOs varies between the different countries. In Poland, the public buses of Warsaw are operated by 6 different PTOs, the biggest one being MZA. The PTO is owned by the city and operates about 77% of the public buses of the city. The 5 other PTOs are a mix of public and private companies. Competition between different PTOs is not always the case, as in Zagreb, where the city owns the only PTO (Zagreb

[81] Wrightbus, STREETDECK FCEV HYDROLINER
[82] Alexander Dennis, Enviro400FCEV

Electric Tram) that operates all trams and buses in the city and its surrounding areas. In Hungary, the biggest PTOs are BKV and Volanbusz. BKV is a local PTO owned by the city of Budapest and operates in the city. Volanbusz operates at a national level: it is owned by the state, and it provides public transport services in 62 cities on top of intercity services, with a fleet of more than 6,000 buses[83].

Public data on articulated buses and coaches in the region is incomplete or sometimes non-existent, thus it is not possible to give an exhaustive and detailed overview of these markets. However, an understanding of the size of the bus fleets across the region is provided in the table below.

Table 7: Total number of buses (incl. buses, coaches, and trolleybuses) - 2022 (Eurostat)

Country	Number of buses (2022)
Slovakia	8685
Slovenia	2782
Romania	54713
Poland	88610
Hungary	17597
Lithuania	7908
Latvia	4303
Croatia	5633
Greece	26910
Estonia	5410
Czechia	21523
Bulgaria	17963

An overview of different cities' fleets shows the different levels of low carbon transition of public buses in the CEE countries. In 2023 in Warsaw, around 1800 public buses were in operation, 62% of which were articulated buses. Among all these buses, 64% were diesel buses, 23% were gas powered buses, 9% were electric Buses and 4% were hybrid buses[84]. This indicates that Polish cities are already committed to the low-carbon transition of their bus fleets. In Croatia, on the other hand, the city of Zagreb's public bus fleet comprised 475 buses, 19% of which ran on gas and none of which was zero-emission in 2022[85].

Several CEE countries committed to decarbonising their public bus fleets, with FCBs among the technologies being considered. The JIVE 2 Bus Roadshow highlighted the local and governmental

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[83] Volanbusz – Our company
[84] Municipal Transport Authority in Warsaw - 2023 Report
[85] ICCT, (September 2022). The rapid deployment of zero-emission buses in Europe

political support for FCBs in many cities of the countries visited (notably Poland, Lithuania, Latvia, Estonia, Czech Republic, Hungary, Croatia, Slovakia and Slovenia).

In Slovenia, the city of Kanal established strategies for using hydrogen in its public transport. In Croatia, the Ministry of Transport has announced a plan to subsidise FCBs and BEVs by 2025. In Lithuania, the government is committed to supporting the acquisition of hydrogen buses in Vilnius.

In Slovenia, Croatia, Poland, Lithuania and the Czech Republic, various cities have announced plans to deploy FCBs by 2025. Demand is particularly strong in Slovakia, where several cities have announced that they will soon be deploying FCBs, for a total of around 125 buses by 2025-2027.

In Poland, regulation will require public transport companies to purchase zero-emission buses only, in cities with more than 100,000 inhabitants from 2025, aiming to achieve a zero-emissions public bus fleet in 2030. Furthermore, 100 to 250 FCBs with 32 HRS are expected to be deployed in the country for 2025 and between 800 and 1,000 buses should be in service by 2030[86]. Such commitment also comes from PTOs which include FCBs in their strategy. For example, Arriva Trnava in Slovakia expects to deploy hydrogen buses for its urban and suburban transport services.

In conclusion, although FCBs are still an expensive solution in many CEE countries and their planned use in bus fleets remains a minority, many cities are beginning to incorporate FCBs into their decarbonisation strategy and are planning to deploy the first units in the coming years. However, this willingness and, more generally, the level of ambition regarding the decarbonisation of fleets vary greatly in this large number of countries.

Several important bus manufacturers are in CEE, some of which develop or already commercialise FCBs.

The Polish bus manufacturer Solaris is the largest manufacturer of zero-emission buses in Europe. The new models from Solaris are a standard 12m FCB (Urbino 12 hydrogen) and a 18m articulated FCB (Urbino 18 hydrogen)[87]. Solaris is already deeply involved in low-carbon bus technologies, which accounted for 80% of its buses sold in 2023. The company owned 15.2% of the zero-emission buses market share in Europe in 2023 and delivered 180 FCBs in 2023 (i.e., 44.5% of FCBs sold in Europe this year). Solaris received orders for more than 700 FCBs, from 40 operators in 10 European countries[88]. Due to the growing demand the company inaugurated a new production hall dedicated to FCBs only[89].

The Czech bus manufacturer Škoda launched the 12-m hydrogen bus Škoda H'CITY 12 in 2022 at the InnoTrans event in Berlin[90]. The pilot operation of this bus started in Prague in July 2023[91].

[86] Ministry of Climate and Environment (December 2021) Krajowy Program Ochrony Powietrza (Update of the national air protection program)
[87] Solaris – Hydrogen
[88] Mobility Portal, (31 January 2024). Solaris announces orders for over 700 hydrogen fuel cell buses in Europe
[89] Solaris, (12 March 2024). Solaris maintained its position as the European e-mobility leader. The company sums up 2023
[90] Sustainable Bus, (22 September 2022). Also hydrogen bus in Skoda's family: H'CITY 12 bus presented today at InnoTrans
[91] DPP, (14 July 2023). Škoda H'CITY hydrogen bus in the streets of Prague

5. Conclusion

5.1 Main barriers and key enabling factors to support the development of fuel cell articulated buses and coaches

The participants to the study were asked to provide insights into the key barriers that they identify as most impactful through a multiple-choice questionnaire. The table below reports the different options included in the questionnaire on the main barriers. The most common choices are highlighted in bold, and the italicised options were only added for the coach questionnaire.

Main Barriers to (further) deployment of fuel cell articulated buses and coaches – questionnaire options	
Limited range	**Limited knowledge of the technology**
Limited offer from OEMs	Longer refuelling time
Higher purchasing costs of FCBs	Potential reduction of passenger space in the bus
Higher operational costs (excl. H2)	**Safety concerns among the personnel**
Higher operational costs (H2)	**Safety concerns among passengers**
Limited lifespan of the fuel cell	Limited maintenance infrastructure
Uncertain maturity of the technology	**Lack of refuelling infrastructure on roads**
Lack of space in depot for the installation of an HRS	*Potential reduction of available luggage hold in the bus*
OTHER	

Based on the responses received through the questionnaires and through the organised interviews, five barriers were emphasised as critical to address to enable further development of hydrogen technology for articulated buses and coaches: the **costs** (OPEX and CAPEX of the buses), the **refuelling infrastructure**, the **knowledge** about the technology, **safety** concerns, and the availability of a diverse pool of **offers from OEMs**. These obstacles were identified across the different countries and regions[92] and are also identical to the main challenges encountered and highlighted in the JIVE projects for the increased deployment of standard (12-meter) fuel cell buses.

<u>Cost (OPEX and CAPEX) and Financial Support</u>

The higher **cost** of purchasing a fuel cell bus compared to diesel technology is one of the biggest obstacles preventing operators from deploying further FCBs within their fleet. This additional cost arises from the CAPEX of the buses which are currently higher than for both conventional diesel and battery electric buses. Moreover, the high costs are also driven by the operational costs, i.e., hydrogen costs (especially 'green' hydrogen) and maintenance costs. The Total Cost of Ownership (TCO), which includes both CAPEX and OPEX, is one of the main indicators considered by bus purchasers, whether it be the public transport operator or the public transport authority, when considering the adoption of a new drivetrain. In many cases, the public transport authorities that plan the decarbonisation strategy and timeline are technology neutral. Costs will consequently be a major determinant in the decision-making process.

[92] Regions specifically refer to the Northern Europe and Central and Easter Europe which were analysed as an overall cluster rather than a country by country overview.

Despite the significant decrease in the prices of the fuel cell buses between the earlier demonstration projects (3Emotion target: max. €850,000 for a 13-meter bus) and the large-scale deployments undertaken under the JIVE initiatives (JIVE 2 target: max. €625,000 base price for a standard 12-meter bus), there remains an important gap in CAPEX costs between fuel cell buses and other vehicles (including BEBs). Subsidies to support the acquisition of vehicles remain essential to stimulate the upscale of fuel cell buses across Europe for all bus models (standard, articulated and coaches). European funds have been fundamental to the development of the market for fuel cell buses. Many countries and regions have also provided national or regional funding support for FCB deployment.

However, the hydrogen mobility market is not yet mature enough to be competitive without grant support. In Germany, the cessation of the federal funding programme for zero-emission vehicles announced in the first quarter of 2024 is expected to cause significant setbacks in deployment projects. This is evidenced by many operators pausing their procurement plans due to the country's policy environment. Furthermore, only operators in federal states granting support for the acquisition of zero-emission buses are launching tenders in 2024. The reliance on policy support combined with insufficient support makes achieving the targets set out in the Clean Vehicle Directive more challenging.

In the Netherlands, despite the availability of a national CAPEX funding support scheme of up to €75,000 per purchased vehicle for operators, interviewees indicated that the grant is just a fraction of the additional costs compared to diesel or battery-electric buses in a TCO comparison over 13-15 years. The main factors leading to the higher costs are fuel (i.e., hydrogen) and maintenance.

In Central and Eastern Europe, several countries that participated in roadshows also highlighted that the **lack of public funding** for fuel cell buses may hinder the development of the technology in the region. This is a key point to tackle as this could lead to an operator preference for other low-carbon transport technologies such as battery-electric buses. There is therefore a need to control the costs associated with this technology to ensure long-term economic viability for operators.

The operational expenditures were also frequently cited as a barrier to further upscaling of the fuel cell bus market. Most of the subsidies employed to date have focused on bridging the CAPEX gap. However, additional support for the operating costs, especially hydrogen costs, could further enable the uptake of FCBs. In England, the BSOG (Bus Service Operators Grant) is a discretionary grant available for operators aiming to support them in recovering some of their fuel costs. For zero-emission buses, the level of support is 22 pence per kilometre. In France, the TIRUERT (*Taxe Incitative Relative à l'Utilisation d'Energie Renouvelable dans les Transports* - Incentive tax on the use of renewable energy in transport) could enable a decrease in the price of hydrogen at the pump, estimated between €2.9 and €6.6/kg of hydrogen by France Hydrogène[93]. Further focus from governments and public funding bodies on such funding schemes would increase the confidence from operators in integrating fuel cell buses in their fleets. While hydrogen prices are expected to decrease with larger production scales, operational costs remain a significant challenge for many bus operators across Europe and are a concern for those considering investing in the technology.

The higher costs can also render the barrier towards adopting fuel cell technology more significant depending on the contract duration public transport operators and public transport authorities establish. In France, these contracts are typically around 5 years. Opting for fuel cell buses to answer a PTA's tender and meet its decarbonisation plan can therefore be perceived as a risk given the small depreciation timeframe in the context of the contract and the remaining uncertainties around the second-hand market. On the contrary, in the Netherlands, the concession contracts are longer. The PTOs

[93] France Hydrogène (2023), Contribution to the Green Industry Bill

interrogated have highlighted that this can create a BEB lock-in effect as many PTOs have already invested significant amounts in the bus technology in past concessions and are therefore planning to continue deploying BEB to decarbonise their fleets as they answer to their daily operation requirements. Therefore, it is essential for PTAs overseeing the fleet renewal and decarbonisation plans to understand the influencing factor contract durations can have on the decisions and approach that will be taken by PTOs.

Overall, costs are a major challenge, and subsidies remain a key enabler to continue the upscaling of the market before it reaches a level where it can sustain and develop with less backing from public entities.

Hydrogen refuelling infrastructure

Another significant obstacle highlighted by the participants to the study is the hydrogen **refuelling infrastructure**, specifically the shortage of public hydrogen refuelling stations on the transportation network and the lack of space in depots for the installation of a hydrogen refuelling station.

The existence of public refuelling stations is particularly important for coaches, which can typically make longer distances trips without a planned return to a dedicated depot. They are also key for operators that either cannot or choose not to build a refuelling station at their depot. The AFIR European regulation adopted in March 2023 is a first step to developing a network of public refuelling stations as it mandates the construction of a hydrogen refuelling stations every 200 km on the TEN-T core network by the end of 2030.

Specifically, many operators for urban public transportation are keener to refuel directly at their depot as this maintains similar operational patterns with conventional diesel buses. These operators are hence less likely to be influenced by the development of an HRS network close to their region of operation. However, the incorporation of refuelling into a depot requires that the operator consider additional factors, such as the regulatory framework applicable to the construction of an HRS to avoid any delays in the approval and commissioning processes or the space required to meet the current and future needs of hydrogen. Nonetheless, even when private refuelling station is installed at a depot, the existence of other public stations in the depot’s vicinity can always be beneficial and act as a back-up solution in case of issues with the primary source of refuelling.

For both public or private stations, high **levels of availability and reliability** is essential to secure further uptake of fuel cell buses. This depends on both the station hardware and software as well as the availability of hydrogen to meet the demand. Ensuring a **reliable supply of hydrogen**, ideally from renewable sources, is crucial. However, this remains a significant challenge for operators, as highlighted in several interviews. As identified throughout the JIVE and JIVE 2 projects, operators should be especially cautious about hydrogen availability when starting their fuel cell bus projects.

The development of hydrogen infrastructure is closely tied to understanding the capacity of the regional and national grids. In some European countries, such as the Netherlands, the grid may not have sufficient capacity to accommodate the grid connections needed to decarbonise public transportation. This reduced access makes it difficult for operators to ensure battery electric buses are charged to the required amount according to their operational schedules. In this context, hydrogen offers an immense advantage as its production can be uncorrelated with the refuelling times. This allows the electrolysers to function during off-peak hours, thereby reducing the strain on the grid.

As highlighted through the study, in addition to the infrastructure challenges, there are other obstacles such as costs that discourage operators from investing in fuel cell buses. Nonetheless, the local fuel cell bus cluster coordinators are leading activities to help broaden the knowledge around the technology and its benefits for public transportation applications and identify opportunities for fuel cell buses to complement the existing BEB fleets.

The importance of refuelling infrastructure is underscored not only by bus operators but by OEMs as well. Several of the OEMs that participated in the study are not yet engaged in the fuel cell bus sector but have begun to develop other fuel cell vehicles. Through these developments, they have identified key requirements for success, with infrastructure being a major barrier to be addressed before their developing fuel cell bus models.

Knowledge and understanding of the technology, including safety

Knowledge of the technology was also pinpointed as a barrier to deployment by the clusters' public transport organisations. Insufficient knowledge on fuel cell buses increases the operator wariness on the vehicle safety, which in turn reinforces the reluctance to deploy these vehicles.

Projects such as JIVE and JIVE 2 play a major role in improving operator awareness of the technology through sharing of key lessons learned with stakeholders beyond the project. The projects have done this is different formats, one of which is the JIVE User Group, which provides organisations outside of the project direct access to learnings and insights from the project partners. Some of the operators in the User Group, such as TMB in Barcelona, EMT Madrid or Wiener Linien, have now purchased and deployed fuel cell buses.

Deliverables, such as the Best Practice Report, can also disseminate learning beyond the originating project. For instance, the Best Practice Report provides valuable insights into the requirements needed to smoothly implement a fuel cell bus project based on knowledge gathered from all the involved PTO and PTAs at each step of the projects' development.

Lastly, activities such as the roadshows in the regions not directly involved in the initiatives (i.e., Central and Eastern Europe) have enabled the local actors to see and test the technology first hand. These events also provided opportunities to interact with hydrogen mobility stakeholders to better understand FCBs and hydrogen in mobility in general. These efforts will necessarily be continued post-JIVE to continue the proliferation of the knowledge generated through the projects.

Gathering and disseminating learnings is especially important for less-demonstrated models. For instance, the deployment of two articulated fuel cell bus models in Barcelona will help inform future deployments of the technology. At a local scale, fuel cell bus operators must continue sharing their knowledge as well with the local stakeholders, such as universities, public authorities, and the citizens to enable them to understand hydrogen mobility and the safety aspects of the technology, such as hydrogen leaks and how they manifest, the difference between a fire caused by hydrogen, by diesel, and by a battery electric vehicle, etc.

Fuel cell buses have been developed for several decades now and the knowledge accumulated by the OEMs allows them to develop more reliable products. For instance, SAFRA, French bus manufacturer, began the commercialisation of its first in-house model, the Businova, in 2018. This bus experienced various challenges which were closely analysed by the manufacturer, enabling SAFRA to develop a new line of buses, the HyCity, born from the accumulated internal knowledge on the technology.

Overall, the feedback provided by the participants and cluster coordinators showed an interest to test and deploy articulated fuel cell buses at different scales depending on the countries. Hence, increasing the knowledge sharing from demonstration projects and enabling longer trial drives for operators is necessary. This was highlighted in the German cluster where operators were keen to have longer trials to help them make more informed decisions and have more time to learn about the technology.

OEMs' offer on the market

Lastly, the limited offerings of the models available from OEMs can also hinder the adoption of the technology. Additionally, the available options do not yet incorporate the requirements of all operators.

From an OEM perspective, further developing their fuel cell business to provide additional offering would first require having a comprehensive overview of the political framework at the EU level. The available support (especially financial support) from governing bodies is a key investment driver for the OEMs because of the prioritisation of the vehicle's TCO by the purchasers. As previously mentioned in the cost section, financial support from public bodies through funding schemes, both for the initial investment and the operational activities, remains necessary for most, if not all, bus operators and public transport authorities.

For coaches, the scope of regulatory frameworks like the Clean Vehicle Directive currently excludes them. However, they are still concerned by the CO2 standards for heavy-duty vehicles which should participate in the development of new zero-emission coach modes.

5.2 Outcomes of the study

The development and commercialisation of fuel cell articulated buses and coaches are occurring at different paces. Fuel cell articulated buses are already a reality and several bus manufacturers selling standard fuel cell buses have been developing and commercialising articulated models to broaden their portfolio and continue expanding their market in Europe.

Conversely, fuel cell coaches are beginning to appear on the market at prototype stages, with several European OEMs and stakeholders developing both new builds and retrofitted models. In 2024, the sector saw progress as two of the retrofitted models were homologated in France, which is key for mass production of the vehicles.

The countries and regions within this study demonstrated different dynamics on demand and deployment of the fuel cell articulated bus and coach markets and more generally, hydrogen in public transportation. These can be divided into the following three groups:

1) The countries/clusters in which the deployment of fuel cell articulated buses is already a reality and where upscaling is expected. For coaches, projects are also being carried out and local actors have begun to engage in the development of the market.
2) The countries/clusters in which the commercial deployment of fuel cell buses is a reality but where the market for articulated fuel cell buses and coaches is not or less developed.
3) The countries/clusters in which the deployment of hydrogen mobility in public transportation is less advanced but where growing interest has been identified, which could bring new opportunities for the fuel cell bus market, including for articulated buses and coaches.

1) **The countries/clusters in which the deployment of fuel cell articulated buses is already a reality and where upscaling is expected. On the coach side, projects are also being carried out and local actors have begun to engage in the development of the market.**

The countries/regions concerned are France, Germany, Northern Italy, and Spain, in which fuel cell buses are already deployed at a commercial level, and in some cases at large scale (50+ buses). Although fuel cell buses constitute a comparatively low share among low/zero-emission options in the national fleets, articulated fuel cell models are starting to be deployed, and announcements for further rollouts are increasing.

France

Pau, in France, was the first city to deploy articulated fuel cell buses. Today, more cities, such as in Saint-Brieux, Le Mans or Dijon, have either announced the upcoming deployment of such buses in their fleets or their interest in deploying these buses. While the deployments are relatively small-scale in many cases, the increasingly widespread development across the territory will improve their knowledge of the technology and its benefits. In other instances, some operators are still testing hydrogen technology in their fleets using standard 12-meter buses before determining if articulated buses could also be a viable solution for their decarbonisation strategy.

Regarding coaches, the transition towards low/zero-emission vehicles is critical as they represent over 70% of the national bus fleet. Projects are already underway in different French regions (Normandy and the Occitanie Region), and various OEMs and retrofitting actors are developing fuel cell coach retrofitted models. Two of these retrofitted models have already been homologated: the GCK retrofitted Iveco Crossway NF 80 and the SAFRA H2-PACK®, used to retrofitted Mercedes Intouro coaches.

Germany

As of the end of 2023, Germany is the largest fuel cell bus market in Europe, with several cities already operating large fuel cell bus fleets of over 50 buses. In Germany, the study as well as a recent survey carried out within the German fuel cell bus cluster on the behalf of NOW highlighted that there is a strong interest from public transport operators and authorities to consider testing and adding fuel cell articulated buses into their fleets. Including the buses that have already been ordered, 185 articulated fuel cell buses are expected to be in operation by the end of 2025. From an OEM perspective, several are already offering fuel cell bus models, and their portfolio is expanding with articulated buses being commercialised as well (e.g., Mercedes).

With regards to coaches, the market for interurban buses (which includes coaches) is quite large in Germany, making the market for hydrogen models significant. Nevertheless, through the study and stakeholders engaged, little concrete outcomes could be drawn on the perspective for the future development of this branch. It is still worth noting that in the field of fuel cell coaches, Flixbus, a private German intercity bus operator with activities across Europe, was involved early on in the fuel cell coach sector through their participation in the HyFleet project alongside Freudenberg Fuel Cell e-Power Systems and ZF Friedrichshafen AG.

Northern Italy

In Northern Italy, the share of fuel cell buses in fleets remains low. However, significant announcements were made in 2023, indicating a growing interest in the region to deploy hydrogen mobility in public transportation. For instance, 130 Solaris fuel cell buses being have been ordered for the city of Bologna[94]. Additionally, orders have also been placed for articulated models, such as for two JIVE/JIVE 2 partners in the cluster: Cologne with 11 Solaris Urbino and 18 hydrogen buses, and Bolzano with 9 Mercedes eCitaro fuel cell buses.

Spain

Spain has only recently introduced hydrogen mobility in public transportation, and the technology adoption is currently driven in Barcelona. The city is involved in the JIVE 2 project and will have 46 fuel cell buses in its fleet by early 2025. Among these 46 buses, Transports Metropolitans de Barcelona (TMB) will trial two articulated Solaris Urbino 18 hydrogen buses. These will be the first articulated hydrogen

[94] Solaris, (11 September 2023). Solaris to carry out the biggest order for hydrogen buses in Europe

buses deployed in Spain, and the performance results will greatly influence further articulated bus purchases by the operator. Articulated hydrogen buses could be well-suited to the city as roughly 40% of its fleet is composed of articulated models. In general, more cities outside of the JIVE projects, such as Madrid, are announcing small-scale deployments to test hydrogen mobility. The development of the Madrid market will continue to be followed.

The available technology offerings in the region are steadily increasing as regional OEMs, such as Irizar (Spain) and Caetano (Portugal), have begun developing fuel cell coach models. For instance, Caetano, in partnership with the Turkish manufacturer Temsa, are developing a fuel cell coach with an expected range of 1,000km. The model was showcased at the Busworld Exhibition in October 2023. Additionally, at the Busworld Exhibition in October 2023, Irizar unveiled their fuel cell coach prototype (i6s Efficient Hydrogen) promising a range of 1,000km as well.

2) **The countries / clusters in which the commercial deployment of fuel cell buses within the fleets of operators is a reality but where the market for articulated fuel cell buses is not or less developed.**

This category includes the Benelux region (particularly the Netherlands) and the United Kingdom. Both regions have been at the forefront of deploying fuel cell buses through early participation in European demonstration projects and have over 20 fuel cell bus fleets in operation.

United Kingdom

In the United Kingdom, cities such as Aberdeen and London have participated in various demonstration projects, building up large fuel cell bus fleets of over 20 buses. Most of the fuel cell buses deployed in the country are double decker models and very few articulated buses are in operation. This is not expected to change in the near future and the market for these fuel cell models in the region is therefore unlikely. Articulated buses are mainly used in niche markets such as passenger transportation in airports where double-deckers are disadvantaged due to the longer loading and unloading times and the complications posed for passengers with luggage. Fuel cell bus models could offer a zero-emission solution in this case. However, the market for the technology remains limited. Given this market landscape, UK-based OEMs are not expected to be involved in developing such models.

For fuel cell coaches specifically, Wrightbus has announced that it is working on the development of a fuel cell coach which be launched in 2026.

Netherlands

In the Benelux region, hydrogen application in public transportation is driven by the Netherlands, several cities of which have been involved in past EU projects, including the JIVE and JIVE 2 projects. However, the pace at which both standard and articulated fuel cell buses are being ordered in the cities already deploying zero-emission buses is slowing down. This could be because PTAs and PTOs are concerned by the cost of the zero-emission fleet decarbonisation options. Currently, high capital costs and hydrogen prices are heavily impacting the attractiveness of the market. In the Netherlands, the concession structure is focused on prices, and as a result, the high costs could slow down the uptake of fuel cell buses, especially when BEB can meet the operational requirements for fleet operators. Nevertheless, the congestion of the electricity grid is a growing concern, the consequences of which is not yet fully addressed. Grid constraints highlight the opportunity for hydrogen mobility's integration in operators' portfolio of zero-emission buses.

The fuel cell bus offerings for all models from local manufacturers also highlights this overall trend in the Benelux region. Previously, VanHool was a major actor in the fuel cell bus sector, developing and commercializing standard and articulated models. Since its bankruptcy and acquisition by VDL, no plans have been announced by the Dutch manufacturer on the hydrogen aspect of the urban bus or coach business.

3) **The countries / clusters in which hydrogen mobility is less advanced but where growing interest has been identified and which could bring new opportunities for the fuel cell bus market, including articulated buses and coaches**

The countries/regions concerned are the Nordic countries (Denmark, Norway, Sweden and Finland) and the Central and Eastern European countries. No large-scale hydrogen deployments have been undertaken under the JIVE projects in these countries[95]. However, several cities had been identified as potential partners at the beginning of the initiatives. Mainly due to the local political landscape, all had to abandon the projects, thus resulting in a Western European focus for JIVE and JIVE 2. As the projects have progressed and more buses were put into operation, the Nordic, Central and Eastern European regions' interest in hydrogen technology and its application in public transportation has grown.

Central and Eastern Europe

In Central and Eastern Europe, there are discrepancies in the level of advancement in engagement and deployment of fuel cell buses, as some cities are developing interests and others have placed orders for vehicles (e.g., Wałbrzych and Płock in Poland). As evident from the JIVE and JIVE 2 bus roadshows, the interest to integrate fuel cell buses in public transportation is only expected to grow across the 13[96] countries visited, as each made announcements and commitments related to the technology.

Nordic Countries

In the Nordic Countries, the fuel cell bus market has developed slowly, with no major deployments so far. Currently, the shift to low-emission public transportation is driven by battery electric and natural gas buses. However, hydrogen bus trials are expected in Sweden in 2025-2026, and interest has been identified in Finland for applications including airport use. Additionally, the JIVE 2 4th bus roadshow will be taking place in the two countries in Q2 2025. Local actors and the cluster coordinator have stressed that sharing knowledge and participating in trials are crucial to stimulate the local market. This is particularly important as hydrogen buses can complement BEBs. The ubiquity of articulated buses in the region makes it a potential market for fuel cell models. Nonetheless, like in most countries and regions involved in the study, costs and pricing issues remain significant barriers to engagement from local PTO and PTA seeking cost-efficiency.

[95] One city in Estonia (Jelgava) joined by the project to deploy 2 demonstration buses following the success of the JIVE 2 bus roadshow.

[96] Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia,

Contributions

We would like to thank all organisations and people who have responded to the online questionnaire and to those who have taken the time to participate in the interview sessions.

Annex

Annex 1: Additional JIVE/JIVE 2 resources

Complementary reports have been developed as part of the JIVE and JIVE 2 projects, contributing to the understanding of the current and future potential European fuel cell bus market. The list of reference is cited below:

- JIVE Final Best Practice Report and Commercialisation Report (D3.26) / JIVE 2 Final Best Practice Information Bank Report (D3.29), June 2024, Sphera and PLANET.
- The potential for hydrogen buses in Europe: Results from the bulk analysis of passenger schedules, July 2024, ERM
- Fuel cell bus deployment in the UK – lessons from JIVE and next steps, June 2024, ERM
- Fuel cell bus rollout in Sweden – Developing pathways to post-JIVE deployment in Scandinavia, November 2024, Vätgas Sverige