Hydrogen Mobility in Visegrad Countries

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Fuel cell buses in Europe: status, outlook, and lessons from the JIVE projects

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Agenda

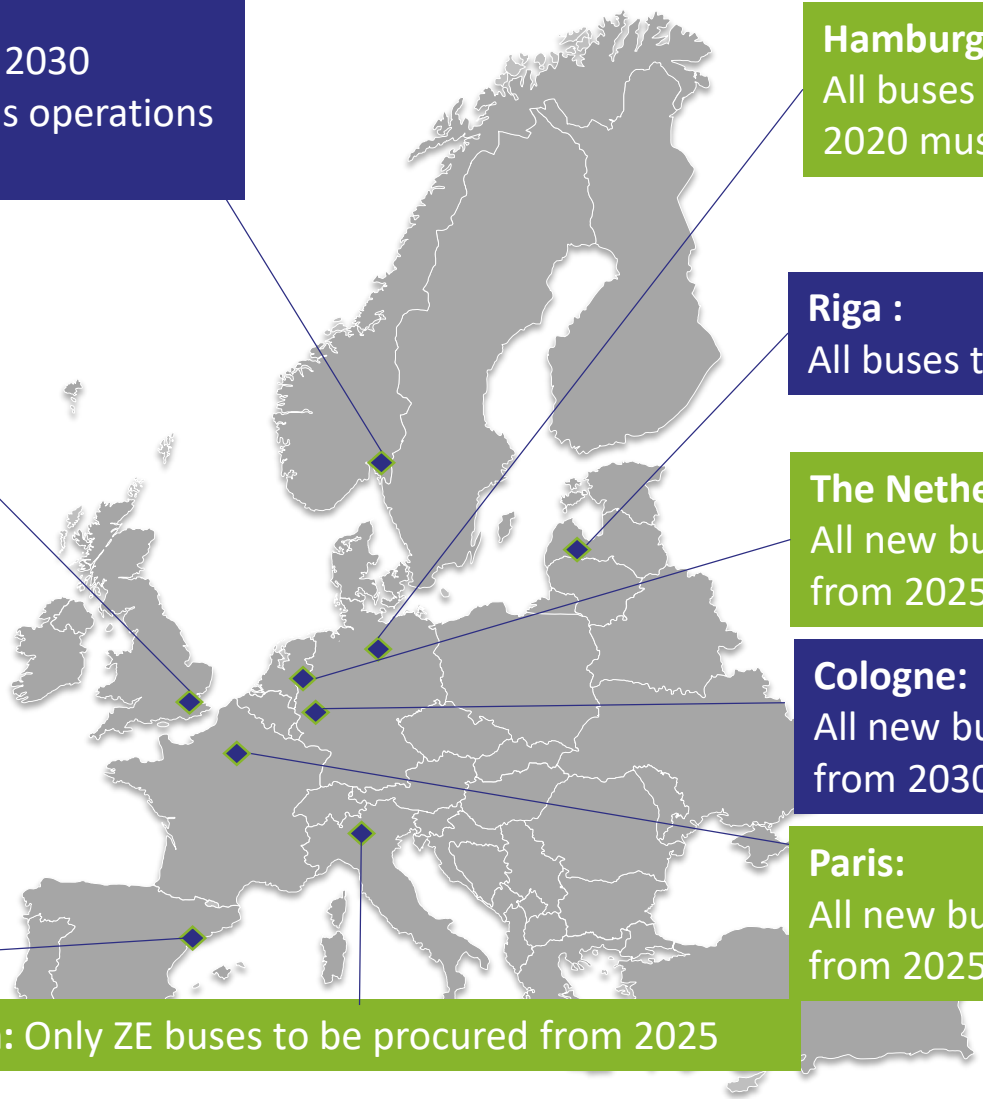
- Background & context
- JIVE – overview & progress to date
- Risks, challenges, and lessons learnt
- Planning larger scale roll-out

Political commitments could create a market for thousands of new zero emission buses per year across Europe from the 2020s

Oslo:
- - 20% transport emissions by 2030
- "Fossil Free 2020" plan: All bus operations shall be fossil free by 2020

London :
From 2020
All new single deck buses to be ZE
All single deck buses in central London to be ZE
From 2025
All new single and double deck buses to be ZE

Barcelona:
Only ZE buses to be procured from 2025



Hamburg:
All buses procured from 2020 must be ZE

Riga :
All buses to be ZE 2025

The Netherlands :
All new buses procured from 2025 to be ZE

Cologne:
All new buses procured from 2030 to be ZE

Paris:
All new buses procured from 2025 to be ZE

Milan: Only ZE buses to be procured from 2025

ZE = zero emission

In parallel, there is a big push towards clean buses at European level

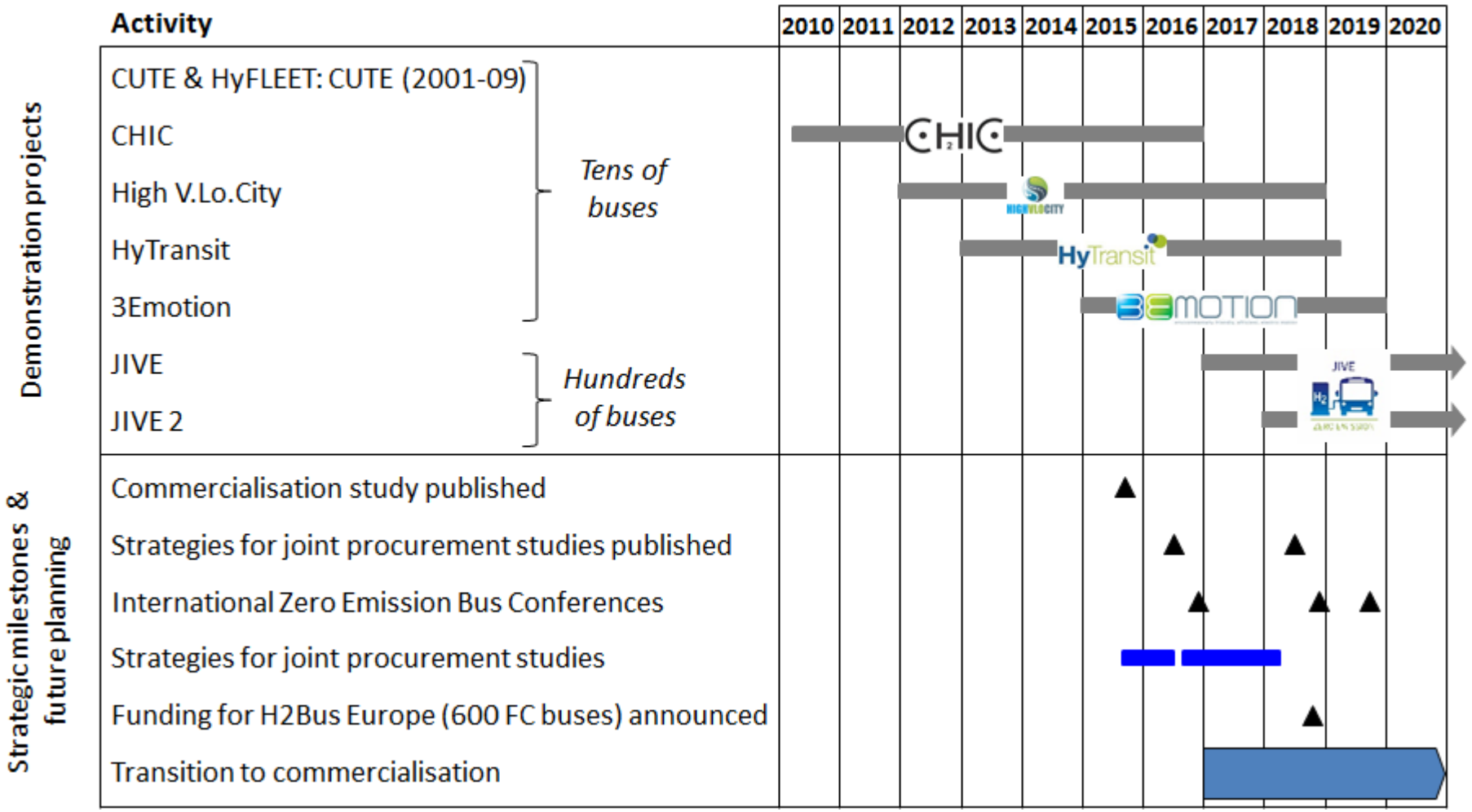
- The **Air Quality Directive** sets max. air pollution limit in each Member State → infringements procedures launched by the European Commission against a large number of Member States.

- The **Alternative Infrastructure Fuels Directive** (2014/94/EU) sets mandatory targets for alternative fuels infrastructure deployment (e.g. charging points). While hydrogen is not mandatory, plans to increase the deployment of hydrogen refuelling infrastructure were included in the National Policy Frameworks of approximately half of the EU Member States that were submitted to the European Commission in November 2016.*

- The **Clean Vehicle Directive** review (Nov 2017): push for cleaner fleets purchased via public procurement. The revision includes a definition of clean vehicles and minimum procurement targets per Member State and per vehicle segment by 2025 and 2030:
  - Regarding clean buses, the min.% to be achieved range 24–45% by 2025 and 33–65% depending on the GDP and population.
  - Half of the minimum target for the share of clean buses must be fulfilled by procuring zero-emission buses (defined as a vehicle that emits less than 1g CO_2/kWh or less than 1g CO_2/km).
  - This requirement is lowered to 25% if more than 80% of the buses awarded in a MS are double-decker buses.

* European countries with hydrogen infrastructure deployment plans / targets include: Austria, Belgium, Czech Republic, Denmark, Estonia, Germany, Finland, France, Hungary, Italy, Netherlands, Spain, and the UK.

Project context

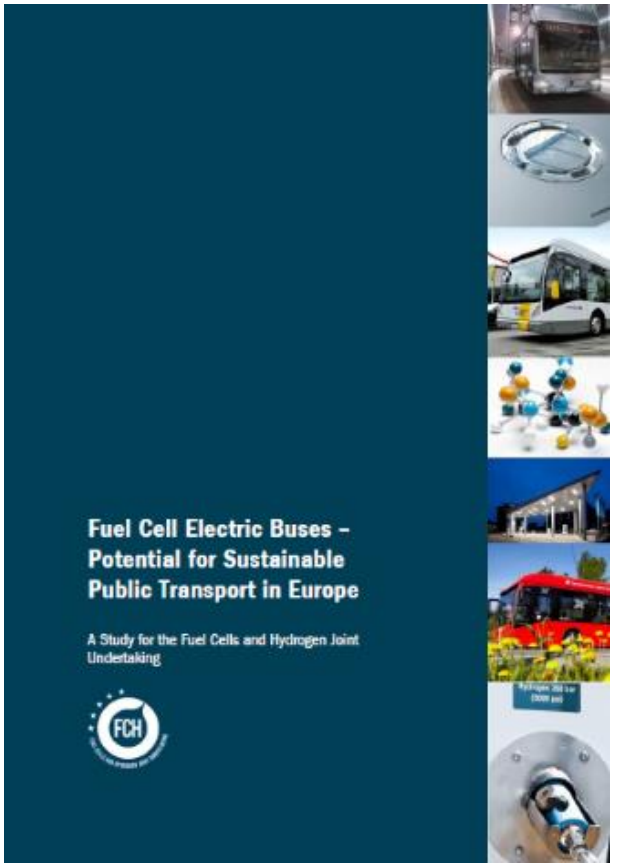


The *commercialisation study* (2015) set out a vision for larger scale deployment of FC buses on a more commercial basis

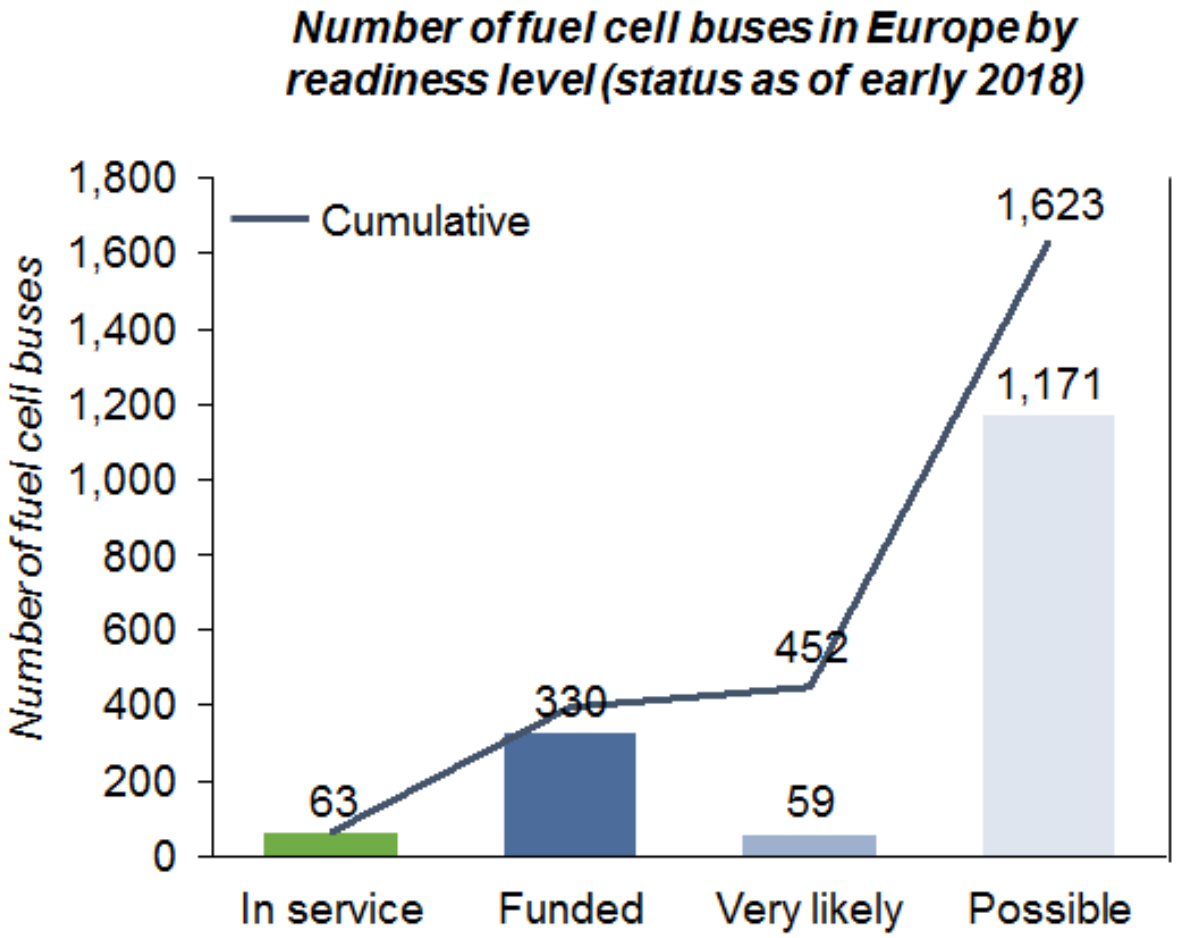
The fuel cell bus commercialisation study (published in September 2015) highlighted the **great potential offered by fuel cell buses to address public transport needs**

Commercialisation vision defined by the 2015 study:

- Increase the number of fuel cell buses – to 300–400 by 2020
- Continue work to reduce costs of buses and hydrogen refuelling infrastructure
- Engage with bus operators to deliver large-scale demonstration projects
- Implement an appropriate public support framework



The “cluster coordination” study identified potential demand for >1,600 fuel cell buses across Europe



Key

In service – buses currently operating.

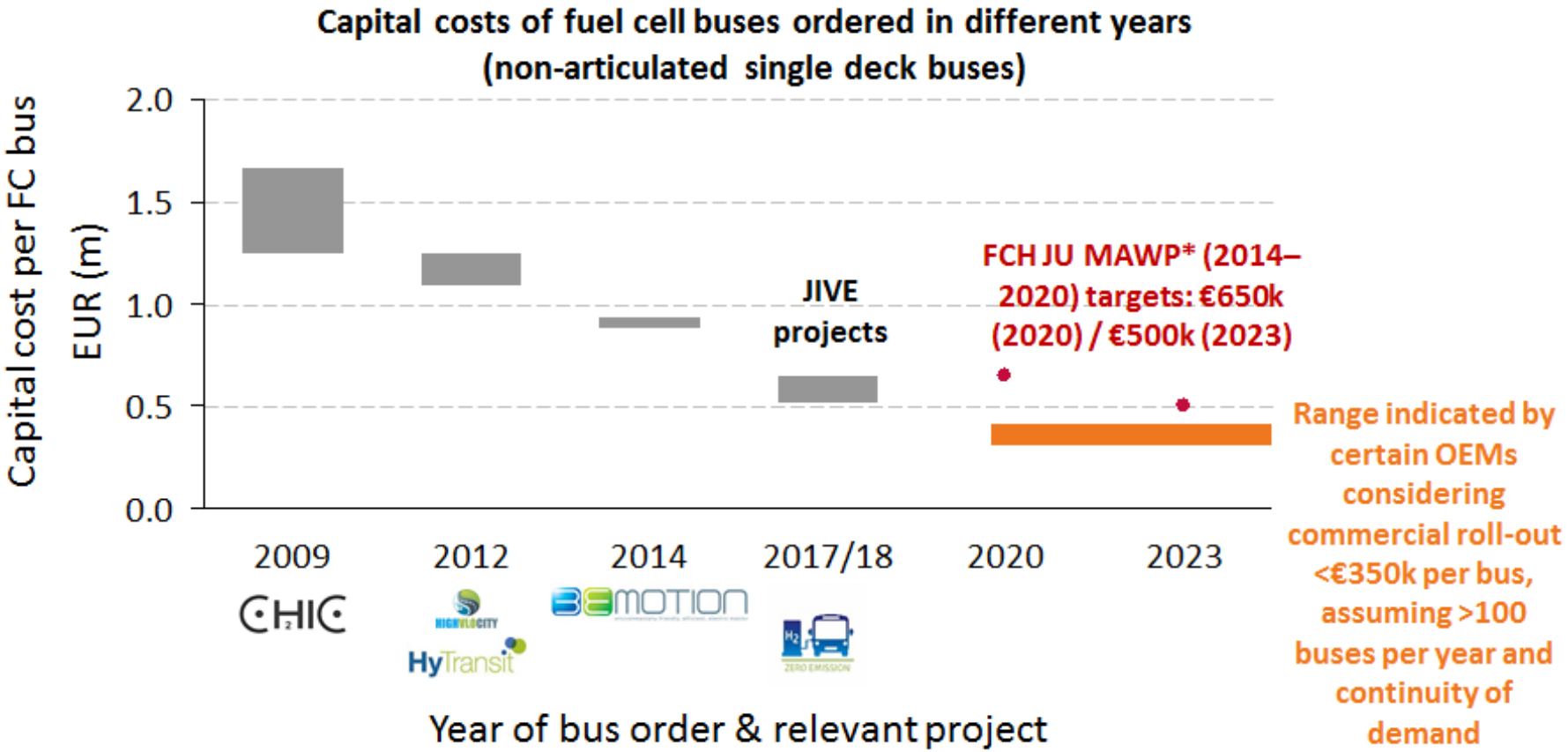
Funded – new buses planned as part of projects that have received funding and are in a delivery phase.

Very likely – new buses planned as part of projects under development / entering a delivery phase.

Possible – represents buses for which there is potential demand but for which no funding has been identified.

Source: Strategies for joint procurement of fuel cell buses (2018), available from www.fch.europa.eu/publications/study-strategies-joint-procurement-fuel-cell-buses

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



* ***FCH JU MAWP*** is the Fuel Cells and Hydrogen Joint Undertaking's Multi-Annual Work Plan, the document that sets out the work plan and strategic targets for the second phase of the FCH JU's programme of research and innovation.

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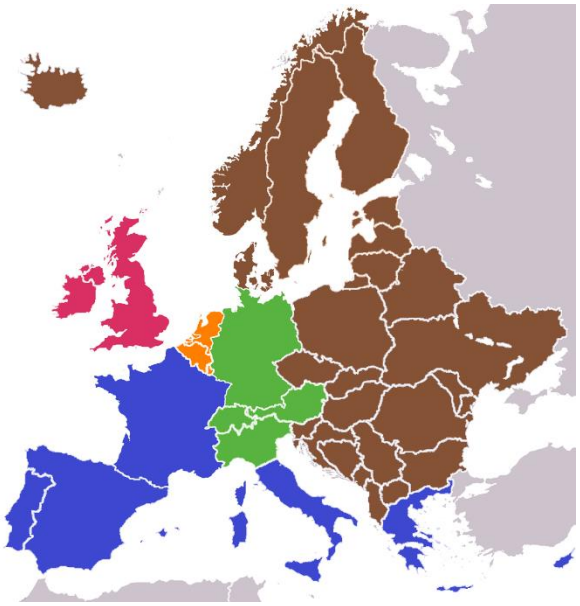
Together, the *JIVE* projects will demonstrate nearly 300 fuel cell buses in over 20 different cities across Europe

Joint Initiative for hydrogen Vehicles across Europe

Objectives

- Deploy large fleets of FC buses and associated refuelling infrastructure
- Achieve a maximum price of €625k for a standard fuel cell bus (JIVE 2)
- Validate large scale fleets in operation
- Enable new entrants to trial the technology
- Demonstrate routes to low cost renewable H_2
- Stimulate further large scale uptake



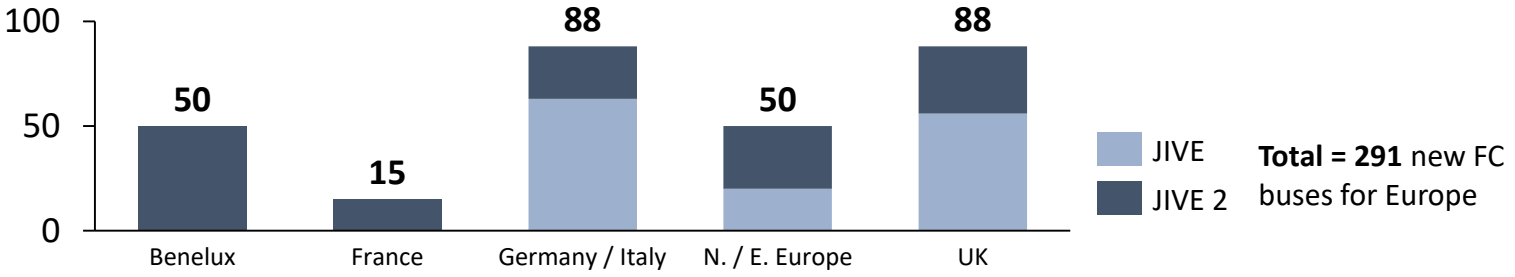
Benelux Cluster (50 FC buses)

France Cluster (15 FC buses)

Germany / Italy Cluster (88 FC buses)

Northern / Eastern Europe Cluster (50 FC buses)

UK Cluster (88 FC buses)



Total = 291 new FC buses for Europe

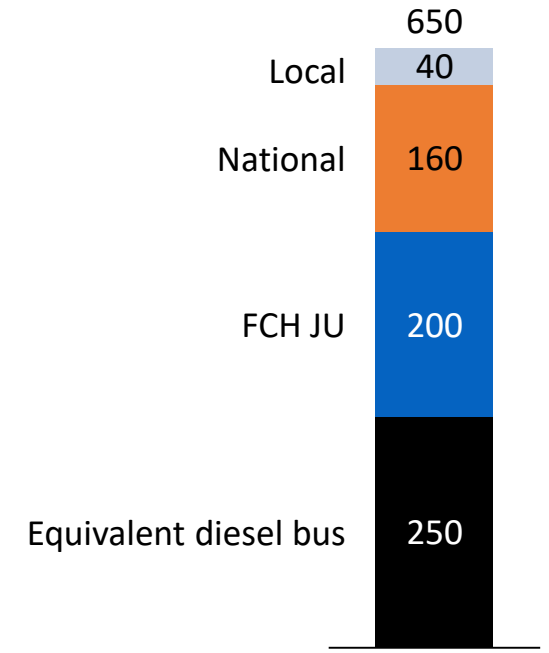
The JIVE project began in 2017; JIVE 2 began in 2018. Both projects are funded by the FCH 2 JU.

Each local project within the JIVE programme relies on funding from multiple sources

- Funding for a large-scale FC bus project was made available under the FCH JU's 2016 Annual Work Plan.
- The FC bus topic included a price ceiling (€650k for standard buses and €1m for articulated vehicles), and a cap on funding: "*The funding per vehicle cannot exceed €200k per standard bus (12/13.5 m), €250k per articulated bus (>18m), provided they are equipped with a full power FC system of at least 50kW*".
- This meant that projects had to secure additional funding from other sources which gives good leveraging of EU funding (but creates additional challenges – see below).

Illustrative funding strategy for covering the capex of a FC bus in JIVE

Values in €k per bus*



* NB this excludes operating costs and costs associated with hydrogen refuelling infrastructure (which also need to be covered).

Procurement and contracting – progress to date

- **Joint procurement framework** established in the UK (see below) with two manufacturers meeting the conditions

- **Bus orders** placed by several cities:
  - Aberdeen (15 Wrightbus buses (double deck))
  - Bolzano (12 Solaris buses)
  - Cologne (30 Van Hool buses)
  - Groningen (20 Van Hool buses for Qbuzz)
  - London (20 Wrightbus buses (double deck))
  - Pau (8 Van Hool buses (5 in JIVE 2))
  - Rhein-Main (11 buses from ebe EUROPA)
  - Wuppertal (10 Van Hool buses)

Capex target of <€650k/bus (base vehicle, non-articulated) met by several different suppliers

- **Longer bus operations planned** – some projects planning for 10 years of operations (compared to 2–3 years in previous demos)

- **Tenders on-going** in several other cities

- **Stimulation of the fuel cell bus market in Europe** (see following slide)

OEMs in Europe are responding to the growing demand for FC buses and preparing to offer new solutions

European bus OEMs with fuel cell buses demonstrators / offering fuel cell buses for sale

ALEXANDER DENNIS

CAETANOBUS

ebe EUROPA

DAIMLER EvoBus

rampini

Safra

ŠKODA

SOLARIS

URSUS BUS

VANHOOL

VDL BUS & COACH

WRIGHTBUS

Non European OEMs active in the fuel cell bus sector

FOTON

YUTONG

TATA

TOYOTA

HYUNDAI

NEW FLYER

Source: Element Energy (based on public announcements). Note: lists are not exhaustive.

FC bus orders in Germany – overview

- Order of 40 Van Hool buses (30 for Cologne, 10 for Wuppertal) confirmed in February 2018
- This is, to date, Europe's largest ever order for FC buses
- Delivery of vehicles planned from autumn 2019
- The order of 11 FC buses from ebe EUROPA for use in Wiesbaden, Mainz and Frankfurt am Main was also announced – 12m and 18m vehicles
- The buses will be manufactured by Autosan in Sanok (Poland) and are due to enter service in autumn 2019

FC bus orders in France – overview

- Pau will be the first city in France to receive fuel cell buses – 18 m buses from Van Hool
- They will be used in Bus Rapid Transit (BRT), system, a world premiere with fuel cell vehicles
- The vehicles were recently unveiled in Pau and the new HRS was inaugurated on 19/09/19.
- Buses due to enter regular service from early 2020.

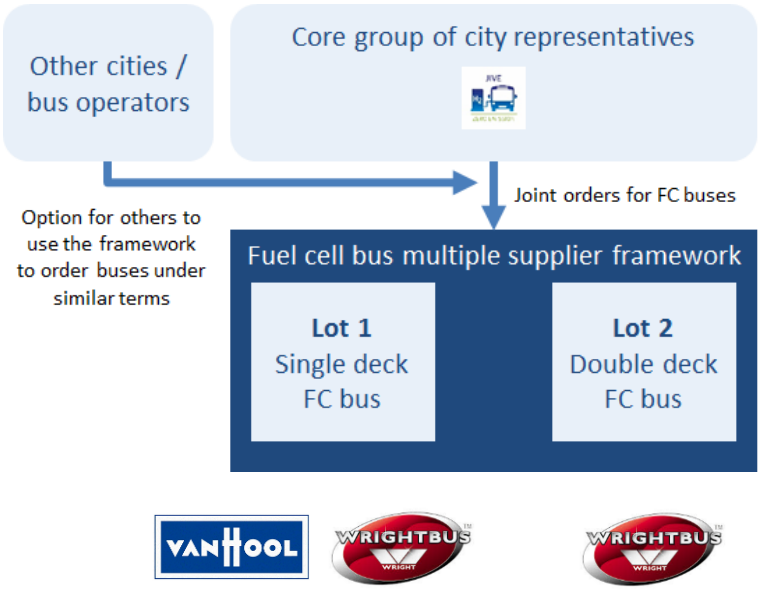
Transport for London has established a framework that allows procurement of FC buses by customers across Europe

Joint procurement framework in the UK – overview

- Provide vehicles with a common specification (with option to tailor buses according to specific needs)

  → **standardisation and economies of scale**.

- Allow consolidated call off orders to be placed.
- Enable other cities (from across Europe) and bus operators to procure buses under similar terms – mechanism for rapid purchase of FC buses.
- The framework is live for four years from 2018.



- London ordered 20 double decker fuel cell buses from Wrightbus in May 2019 – they will be delivered in 2020.

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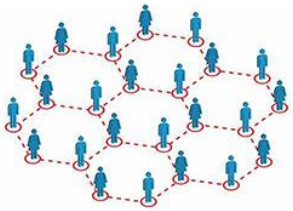
Emerging conclusions / first lessons learnt

- Responses to the procurement exercises suggest that there is a **growing interest in offering fuel cell buses from suppliers worldwide**
- **Fuel cell buses below the JIVE / JIVE 2 target prices (€650k / €625k for standard single deck buses) are now available** to customers willing to commit to sufficient volumes
- Some suppliers have indicated **far lower prices are possible** (e.g. well below €450k) with sustained orders of around 100 buses per year per OEM – at these levels **fuel cell buses could be the lowest cost zero emission option**
- The joint procurement exercises have been effective in aggregating demands and stimulating the supply side

Risks and challenges associated with FC bus deployment – lessons to date (1/2)

- **Joint procurement exercises: not always the most appropriate model** to facilitate the commercialisation of fuel cell buses given the complexity – linking projects has downsides as well as benefits
- **Multiple sources of funding** – means FCH 2 JU funding is well leveraged, but this adds complexity and timescale challenges
- **Need to procure HRS / H_2 supplies in parallel with buses** – fuel costs are a critical element of the total cost of ownership
- **Achieving affordable maintenance costs** for FC buses and finding an appropriate risk sharing approach given the uncertainty over lifetime costs
- Challenge for cities / operators to commit to ordering large fleets without full certainty over lifetime costs – **"all-in" offers may be attractive to early adopters**



Risks and challenges associated with FC bus deployment – lessons to date (2/2)

- **Relatively limited operational data** for latest generation buses leads to challenges in planning and budgeting for whole-life costs. Using conservative assumptions may undermine the investment case – one option is to secure the "project" for a relatively short period (e.g. three years of operation), then reassess on-going costs when better data are available.
- **Technical challenges** – e.g. providing sufficient range and passenger carrying capacity (especially for double deck buses).
- While several new OEMs are entering the market, **the number of FC bus models available remains relative limited** (e.g. compared to battery electric buses). Furthermore, there may be **long lead times** for FC buses from some suppliers.

FC bus procurement in the UK – lessons learnt (1/2)

Bus Operator Engagement

- Early engagement with operators is critical
- Agree selection process on how a FC bus operator will be appointed
- Obtain their preferred approach to operating and maintaining the vehicles
- Identify potential deployment garages and routes
- Set and agree roles, responsibilities and expectations of all parties

Early Market Engagement

- Identify the challenge to be overcome
- Identify suppliers/OEMs who potentially have the capability to meet the challenge
- Engage with potential suppliers/OEMs to explore their appetite on the requirement, ability to mobilise, product offers
- Use this as a opportunity to test assumptions and align expectations
- Ensure the output of this aligns to the procurement approach and specification

FC bus procurement in the UK – lessons learnt (2/2)

Tender Development

- Agree standard specifications with bus purchaser (JIVE partner) and operator
- Lean on organisations with wider experience in the sector (operators)
- Seek further clarity over operations and maintenance
- Ensure you know your specification and understand what you want and what the market can offer
- Provide the suppliers with realistic timescales.....**and stick to them!!**

Contract Award & Call Off

- Re-evaluate the operators' requirements in terms of specification of the bus and approach to maintenance
- Engage with the supplier..... Provide them with realistic timescales.....**and stick to them!!**

The CHIC project found that appropriate staff training is key to a project's success

In the CHIC project dedicated training sessions were developed for:

- **Bus drivers**: training included explanation on the technology, emergency training, procedures to follow in case of failures, bus refuelling trainings
- **Maintenance training for technicians** to enhance their understanding of hybrid diagnostics systems, hybrid, gas systems and high voltage trainings
- **First responders**: training on risk assessment and handling of hazardous material

Lessons learnt

- **As all innovative technologies, fuel cell buses require further training compared with diesel buses**. Electrical skills are required on top of mechanical skills; adaptation has been easier for staff already trained on hybrid buses
- Enough time should be dedicated for training, and the training should be practical
- Start by **selecting a pool of motivated drivers** and let them drive the buses frequently
- Explain to the staff that they are **part of a global picture** (trial taking place in other cities/countries) has proved to be useful to increase their motivation for the project

Source: CHIC Emerging Conclusions

Lessons from other preceding projects

Project	Short description	Successes	Lessons Learnt
CHIC	56 fuel cell buses in 8 cities	• Operating range similar to that of diesel buses (>350km) • Refuelling time <10mins • 85% CO_2 emissions reduction compared to diesel buses* • Satisfaction for end users	• Improve bus availability through resolving technical issues and increasing scale • Reduce bus and hydrogen price through commercialisation • Harmonise regulations
HIGH V.LO.City	14 fuel cell buses and HRS deployed in 4 cities	• 14 buses in full operation with >85% availability • 97% availability of stations • V. good customer acceptance • 102 tonnes of CO_2 saved**	• Ensure sufficient supply chain in place, with spare parts kept on site • HRS can easily be scaled up when necessary and should be located close to bus depot
NewBusFuel	Engineering studies on large-scale hydrogen refuelling at bus depots	• 13 engineering studies defined optimal designs, hydrogen supply routes, commercial arrangements and practicalities for HRS capable of providing fuel to fleets of fuel cell buses (75–260 buses)	• Accessing low cost, renewable energy supplied will be key to generating cost-effective hydrogen • Two project reports assist procurement for bus operators with no prior experience of hydrogen available https://www.fuelcellbuses.eu/publications

* Across the lifecycle of the bus when H2 produced from renewable energy sources; **compared to Euro VI vehicles

Top tips for future FC bus projects – scale is key to achieving a commercial proposition

- **Scale is important:**
  - ✓ Reduces capital costs and H_2 costs
  - ✓ Allows more robust service and maintenance arrangements
- **Maintenance arrangements need to be robust:**
  - ✓ Aim to have your own mechanics trained quickly
  - ✓ Good spare parts inventory nearby, with regular and FC components
  - ✓ Ensure robust contracts with OEMs with penalties for poor availability
- **Procurement should be simple:**
  - ✓ Structure should mirror typical arrangements between OEM and bus operator (without transport authority being involved)
  - ✓ Contract directly with OEM, not a system integrator
- **Some depot modifications will be required**:
  - ✓ Sensors & vent pipes in buildings, check ATEX requirements
- **Ensure the drivers are positive about the change**:
  - ✓ Give training to ensure understanding of the technology and its benefits

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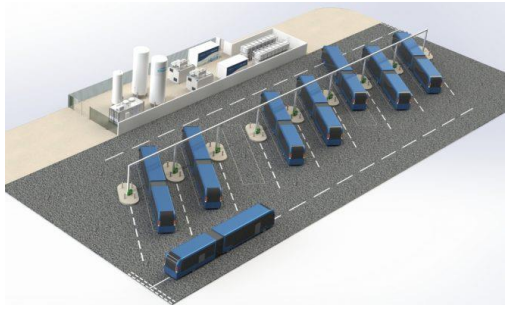
FC bus deployment beyond JIVE – the commercial phase..

- Several cities and hydrogen companies are now looking at how to move to the next, commercial phase beyond the JIVE deployments.
- There are some important ingredients:
  - **Scale of bus demand** – hundreds of units per year appear to provide adequate cost reductions
  - **Scale of demand at a depot** –required to reduce H_2 price
  - **Access to low cost energy** – critical to achieving affordable hydrogen, best option is location dependent



- Achieving this will require continued commitment to **zero emission policies**, without prejudice against hydrogen…
- … and willingness from operators to **commit to large scale fleets**, ideally in concerted procurements.
- With this, hydrogen looks capable of being the most affordable and most flexible zero emission option for urban buses, particularly for challenging routes (high daily mileage, large vehicles etc.).

Thank you for your attention

Project coordination
Element Energy Limited

Project dissemination
Hydrogen Europe

ZERO EMISSION

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