



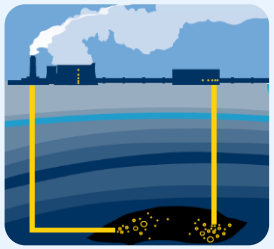



Fuel cell bus joint procurement clusters

FCH JU Stakeholder Forum

Nov 2017

Element Energy Ltd

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Some history – CHIC and other demonstration projects - conclusions & next steps

CHIC project conclusions

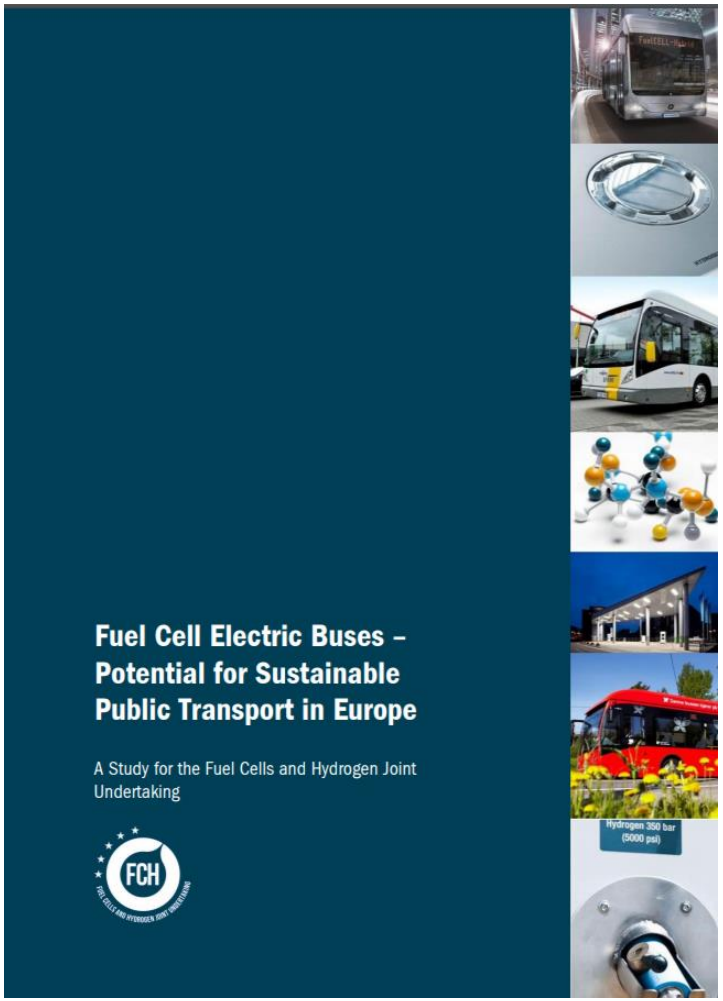
Hydrogen fuel cell buses can offer:

- ✓ **Operational flexibility** (comparable to diesel)
- ✓ **Zero local emissions**
- ✓ **Reduced CO_2 emissions,** with a pathway to zero emission
- ✓ **Satisfaction for end users** (drivers & passengers)

Next steps

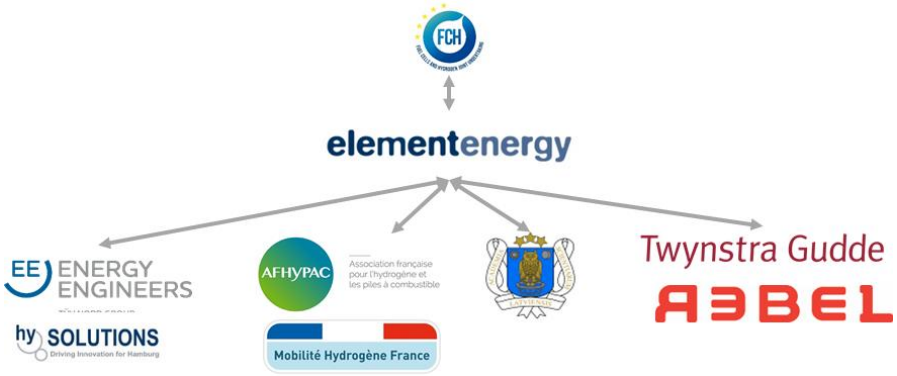
- ➢ **Improve bus availability** – by resolving teething technical issues & increasing scale
- ➢ **Reduce bus prices** – coordinated commercialisation process (see below)
- ➢ **Harmonise regulations** on hydrogen refuelling stations – work underway on international standards

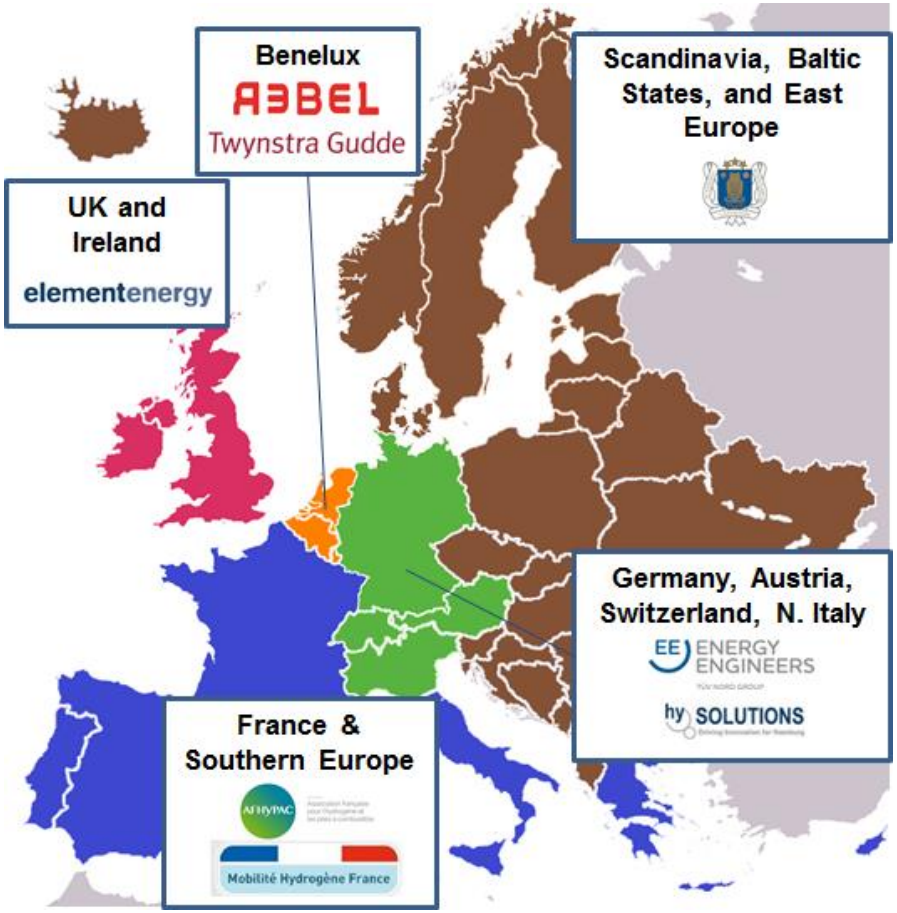
In parallel two major consultancy projects provided a strategic direction for the next steps on fuel cell buses



NEAR TERM AIM – establish a coalition of willing cities to deploy ~400 buses by 2020

Element Energy has been coordinating demand aggregation for fuel cell buses across five "clusters" since 2015





Strategies for joint procurement of fuel cell buses (July 2016)

www.fch.europa.eu/sites/default/files/Strategies%20for%20joint%20procurement%20of%20FC%20buses_0.pdf

The current phase of work (2016/17) seeks to build on achievements to date and prepare the market for larger scale uptake of FC buses

Overarching project vision

- **Reduce fuel cell bus costs** to a level close to hybrid buses and eliminate the need for subsidy by stimulating deployment of around 1,000 fuel cell buses.
- Work with bus suppliers and customers to overcome the impasse of OEMs waiting for large orders before reducing costs and public transport authorities waiting for economic fuel cell buses before placing large orders.

Specific objectives

The cluster coordinators are tasked with:

- **Supporting the on-going procurement activity** for coordinated purchase of fuel cell buses in the UK, Germany, Northern Italy, and Northern / Eastern Europe.
- **Initiating new procurement exercises** in further European regions and cities.
- **Increasing the number of cities participating** in each cluster and supporting each partner in developing plans for fuel cell bus deployment.
- **Developing strategies for financing many hundreds of buses** beyond the current subsidised phase.

The availability of lower bus prices and match funding has made bus projects economically plausible for operators

Lower prices has driven demand

Lower prices have led to a number of municipal partners starting to push the fuel cell bus option.

The proposition has been

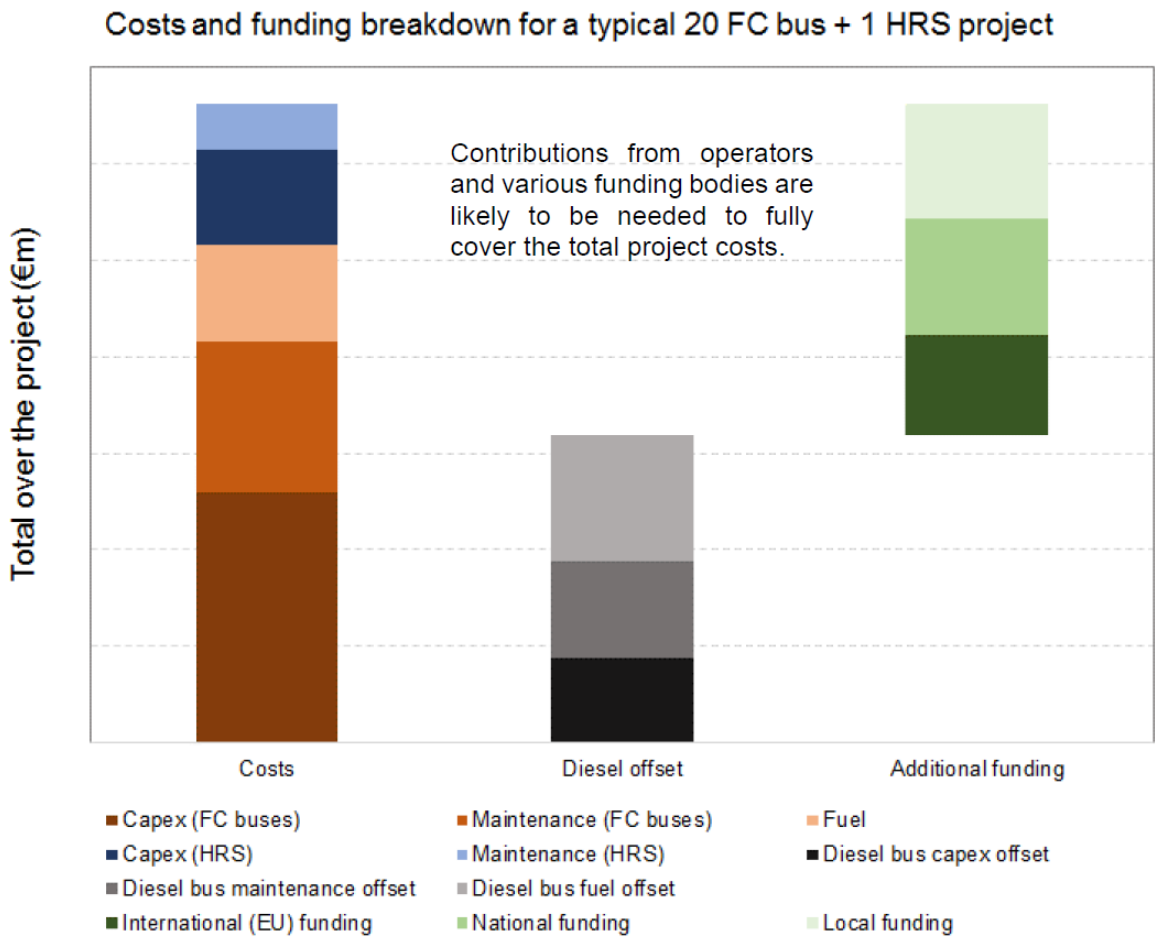
Max bus price = €650k

FCH JU funding = ~ €200k

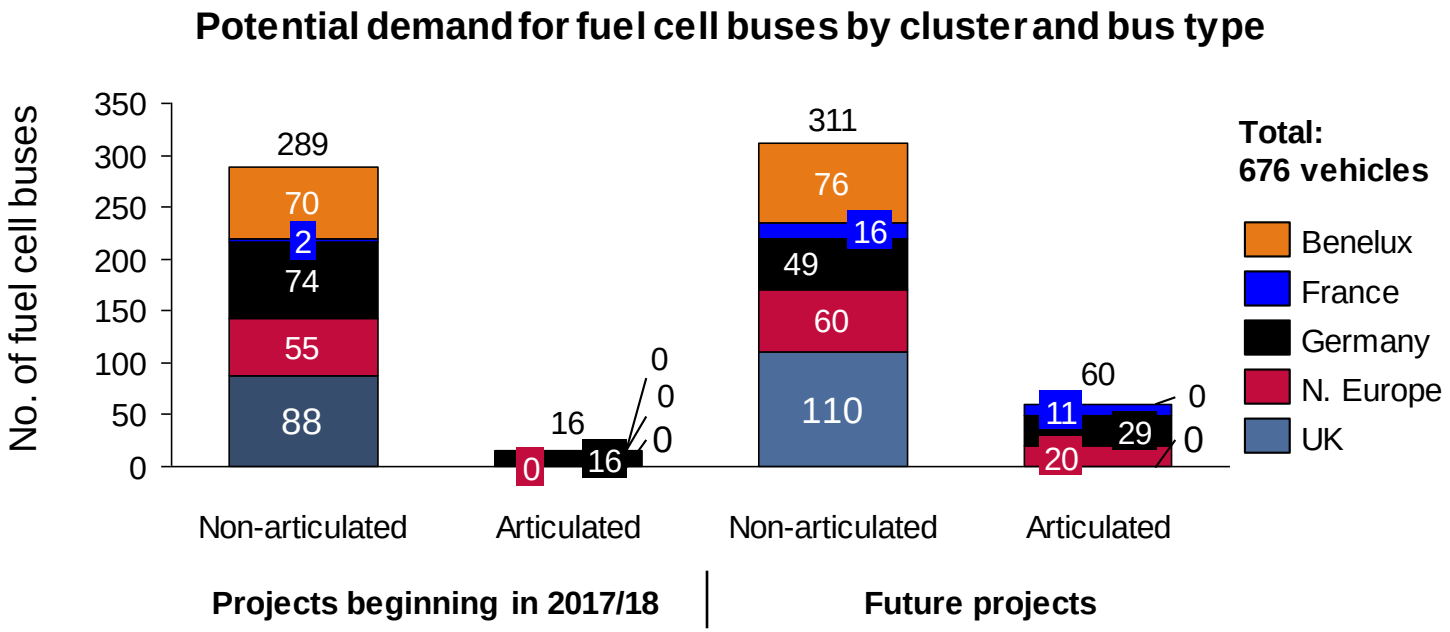
Therefore you can have a fuel cell bus for €450k

It has been the ability to discuss more practical prices which has driven this beginning of demand

Even with these reduced prices there is still a need to seek a range of public funding sources.



Working with city representatives, the cluster coordinators identified demand for >600 fuel cell buses across Europe



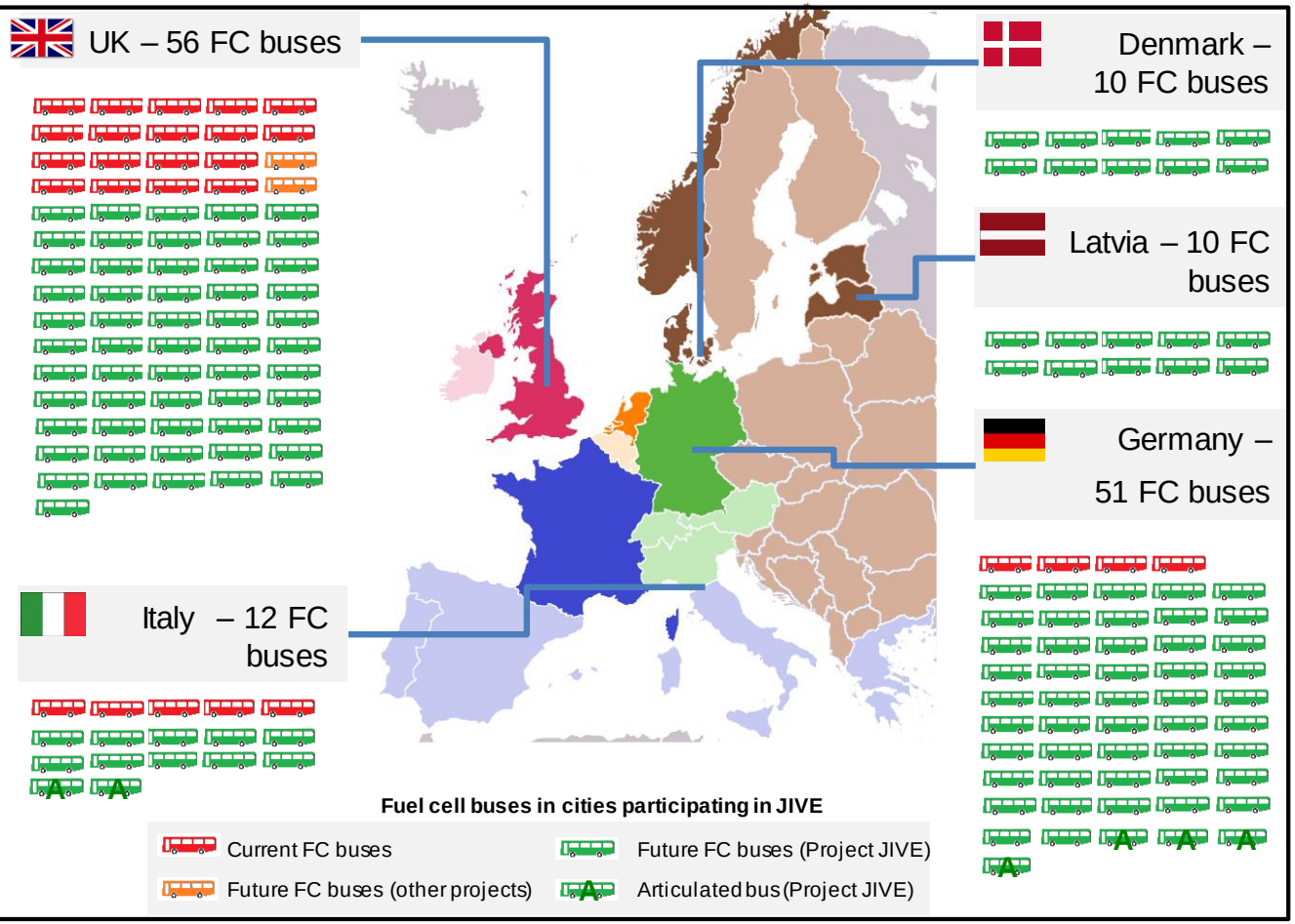
Note that these are provisional estimates based on the work of the cluster coordinators to date. No firm commitment has been made by the cities listed above. While the cluster coordinators have sought to provide realistic and relatively conservative deployment numbers, in practice these figures may fall as more detailed local feasibility work is undertaken.

The JIVE project will help commercialise fuel cell buses through a large-scale demonstration across five Member States

JIVE: Joint Initiative for hydrogen Vehicles across Europe

Objectives

- Deploy 139 FC buses across nine cities
- Achieve 30% cost reduction versus state of the art
- Operate 50% of the vehicles for at least 36 months
- Deploy the largest capacity HRS in Europe
- Achieve near 100% reliability of HRS
- Demonstrate technological readiness of FC buses and HRS
- Encourage further uptake



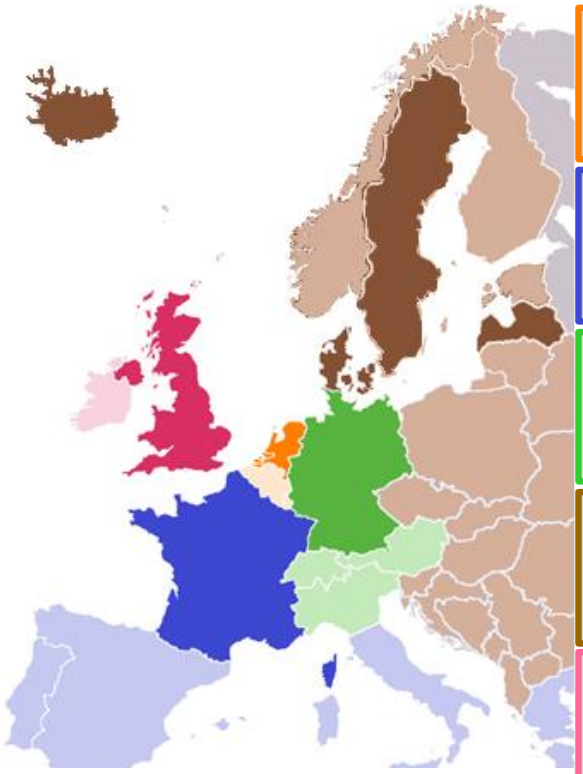
JIVE began in January 2017 and will be a six year project

The *JIVE 2* project was submitted in April 2017 – this could support another 152 buses

JIVE 2: Joint Initiative for hydrogen Vehicles across Europe Phase 2

Objectives

- Deploy 152 FC buses across 14 cities
- Achieve a maximum price of €625k for a standard fuel cell bus
- Operate buses for at least three years / 150,000 km
- 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



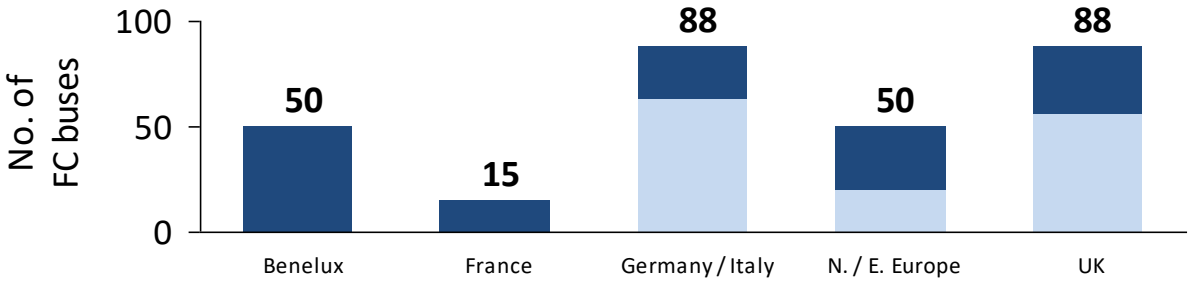
Benelux Cluster (50 FC buses)

France Cluster (15 FC buses)

Germany / Italy Cluster (88 FC buses)

Northern / Eastern Europe Cluster (50 FC buses)

UK Cluster (88 FC buses)



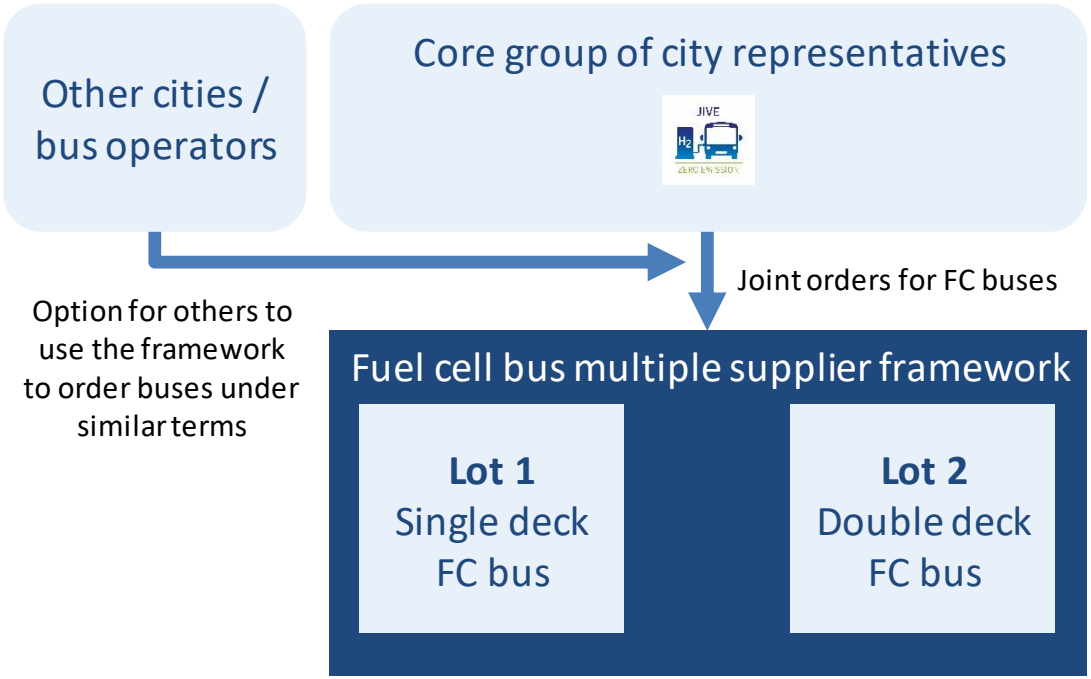
Total = 291 new FC buses for Europe

"JIVE 2" builds on the objectives of the "JIVE" project, which began in January 2017. See www.fch.europa.eu/news/launch-project-jive-large-scale-deployment-fuel-cell-buses-europe

TfL has led an exercise to establish a framework that allows joint procurement of fuel cell buses by public and private sector organisations

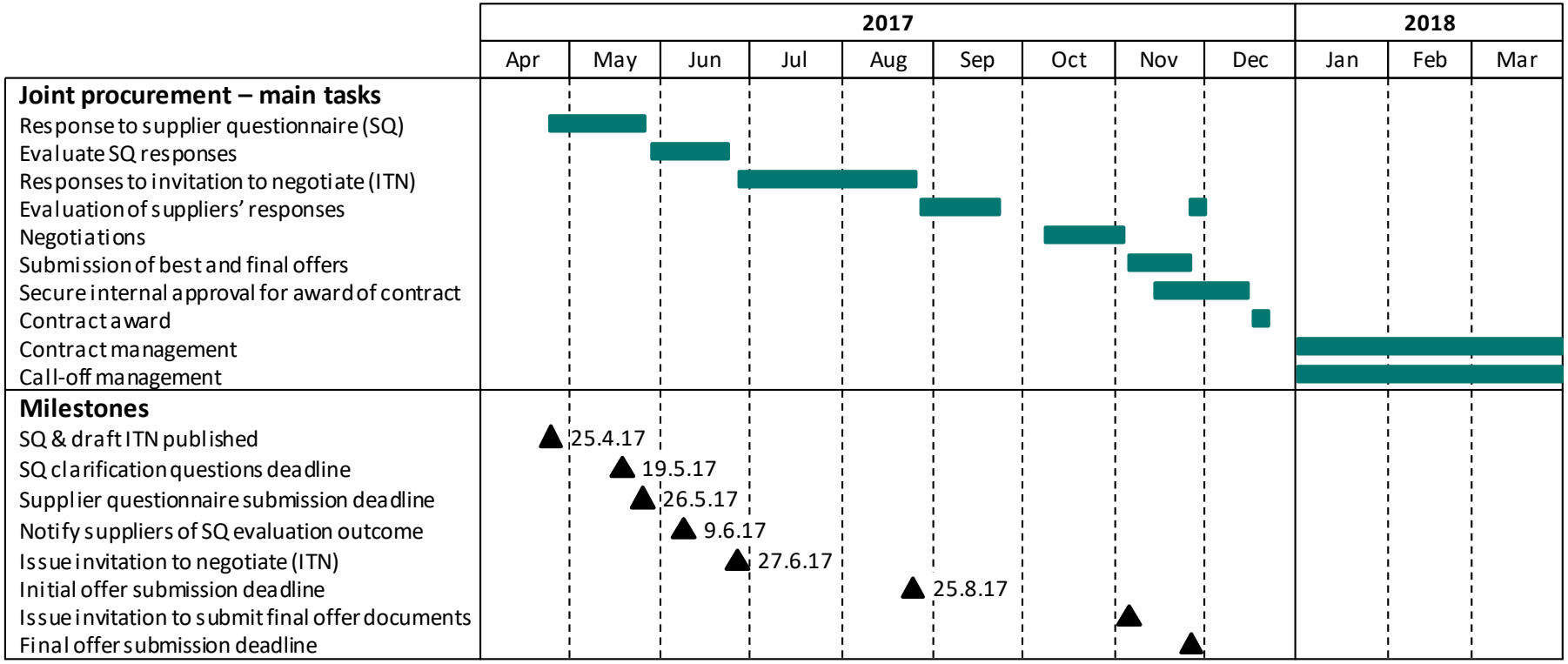
Framework for joint procurement of FC buses – key features:

- Provide vehicles with a common (base) 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 UK / European cities and UK bus operators to procure buses under similar terms.
- Live for four years from late 2017.



Framework rules => there may be more than one supplier per Lot. However, the bus order for each respective Lot will only be awarded to the supplier which provides the most advantageous tender at the call off stage. Therefore, if all cities decide to order the same type of buses (double / single deck), the whole contract will be awarded to one supplier.

The Framework will be in place from late 2017 and is the result of a fully compliant procurement exercise that began in April



- Negotiations with potential suppliers are on-going as of autumn 2017.
- TfL plans to have the framework in place by the end of 2017, with the first batch of orders following shortly thereafter.
- H2 station discussions are handled separately by each city.

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

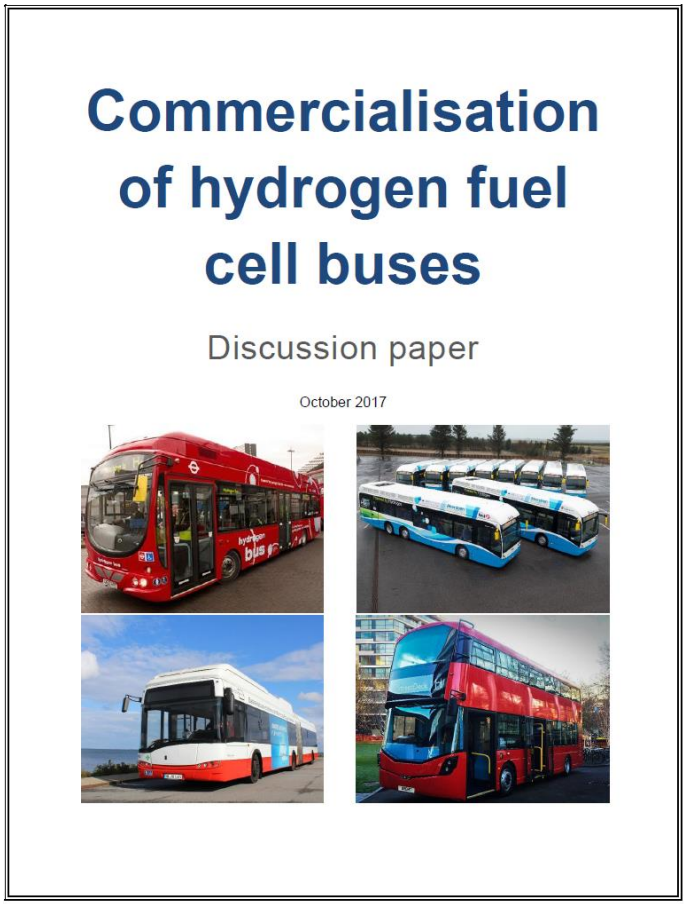
Key players

OEM (country)	Relevant experience / products
ALEXANDER DENNIS (UK)	Funded for a proof-of-concept hybrid fuel cell double-decker bus with Arcola Energy and Warwick Manufacturing Group.
EvoBus (DE)	Demonstrated 17 FC buses in the CHIC project, tens of FC buses produced to date. Releasing electric Citaro in 2018 and FC in ~2020 
rampini (IT)	Built the "H80" FC bus in 2007 (>3,000 hrs / 50,000 km covered). New FC bus "H120" being homologated. Plans to produce tens of FC buses over the coming years. 
SOLARIS (PL)	Two E18 FC buses in service in Hamburg. Ten FC range extender trolleybuses on order for Riga. Single deck products being offered on the Urbino platform. 
SOLBUS (PL)	First FC bus delivered to Syntus (Dutch bus operator) in mid-2016. 
URSUS BUS (PL)	Offers the "City Smile" 12m FC bus, based on a range extender concept. Demo bus present at the IAA 2016 (Hannover). 
VANHOOL (BE)	Market leader - >40 FC buses operating in Europe and the US 
VDL BUS & COACH (NL)	Four FC buses delivered in 2011 as part of demonstration activities. 
WRIGHTBUS (UK)	8 single deck FC buses in London as part of the CHIC project. Single and double deck FC buses available for order from 2017. 

Note: this list is not exhaustive.

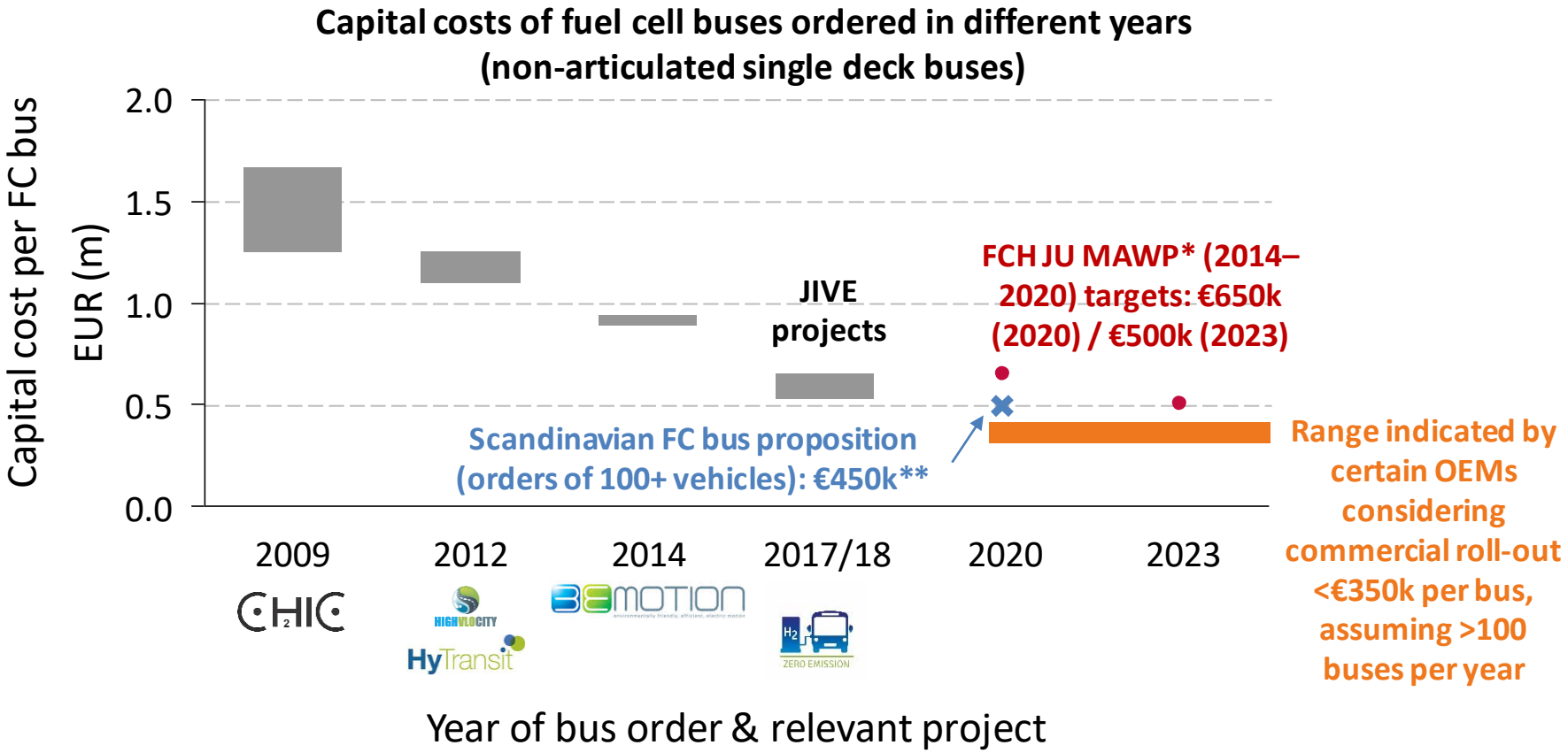
In this context, we have been working on planning fuel cell bus deployment beyond the subsidised phase

- As part of our current contract with the FCH JU, we are exploring how to scale-up FC bus deployment beyond the subsidised phase.
- This has involved holding discussions with a range of stakeholders (OEMs, infrastructure providers, potential investors, etc.) to develop a vision for the sector.
- We have prepared a *White Paper* that makes the case for FC buses and sets out the next steps for key actors: policy makers, bus OEMs, component suppliers, infrastructure providers, and bus operators.



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

Evolution of fuel cell bus costs in Europe

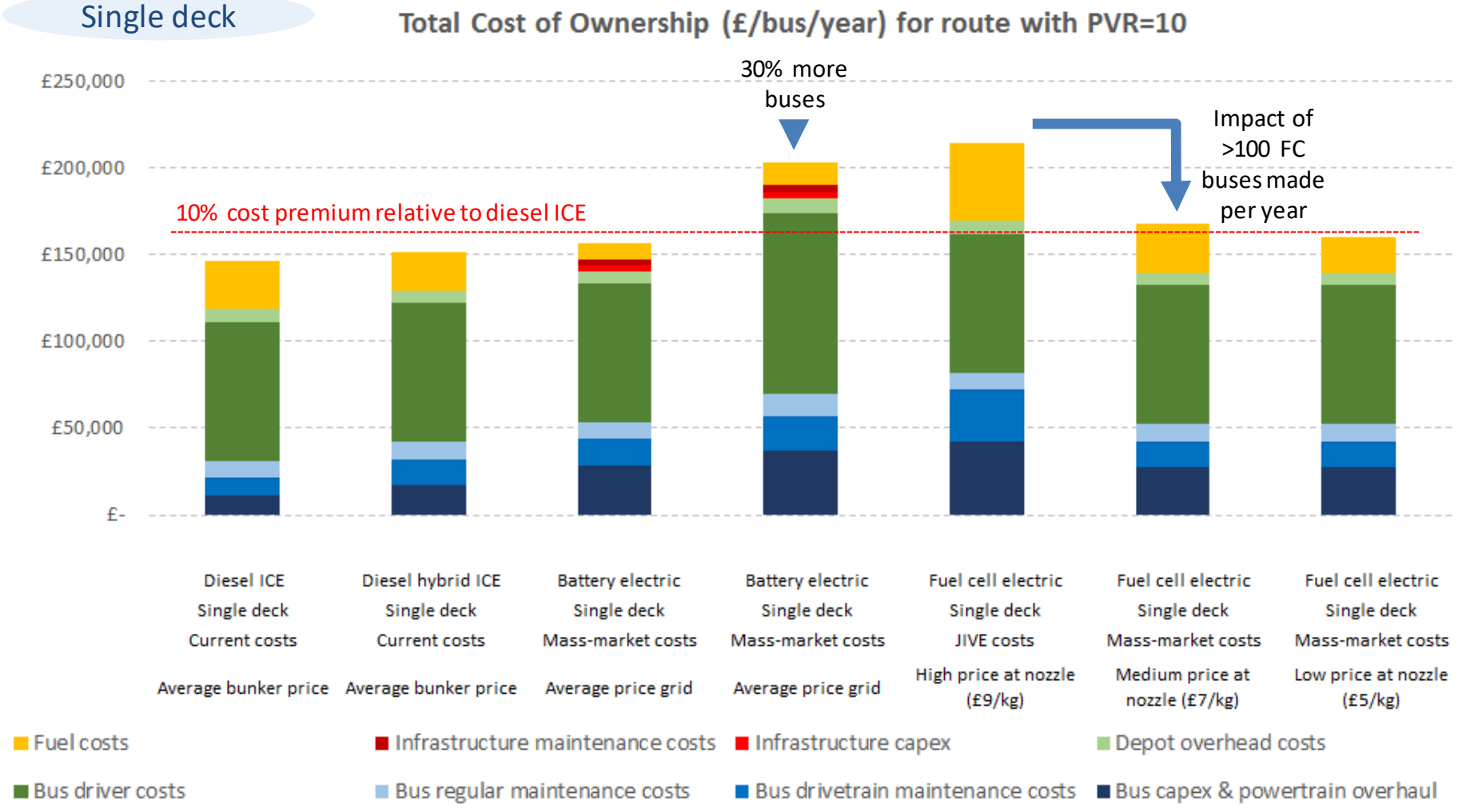


* ***FCH JU MAWP*** is the Fuel Cells and Hydrogen Joint Undertaking's Multi-Annual Work Plan, the document that sets out the work plan and strategic targets for the second phase of the FCH JU's programme of research and innovation.

** See http://hydrogenvalley.dk/white-paper/.

Cost and performance data validated by UK OEMs suggests that FC buses could compete with other zero emission options without subsidy

Single deck



PVR: peak vehicle requirement.

Single deck bus fleet: key assumptions – calculations based on a 10 bus route

		Powertrain:	Diesel ICE	Diesel hybrid	Battery	Battery	Fuel cell	Fuel cell
		Bus type:	Single deck	Single deck	Single deck	Single deck	Single deck	Single deck
		Cost scenario:	Current costs	Current costs	Mass-market	Mass-market	JIVE costs	Mass-market
Bus availability	%		90%	90%	90%	90%	90%	90%
Additional vehicle requirement	%		0%	0%	0%	30%	0%	0%
Bus capex	£/bus		140,000	210,000	320,000	320,000	500,000	305,000
Bus lifetime	years		14	14	14	14	14	14
Powertrain overhaul capex	£/bus		20,000	30,000	80,000	80,000	90,000	79,000
Powertrain lifetime	years		7	7	7	7	7	7
Bus drivetrain maintenance	£/year/bus		10,000	15,000	15,000	15,000	30,000	15,000
Diesel consumption	l/100km		37	30				
Electricity consumption	kWh/100km				160	160		
Hydrogen consumption	kg/100km						8.00	6.50
Diesel price	£/litre		1.20	1.20				
Electricicty price	£/kWh				0.10	0.10		
Hydrogen price	£/kg						9	7 – 5
Bus regular maintenance	£/year/bus		10,000	10,000	10,000	10,000	10,000	10,000
Driver salary	£/year		40,000	40,000	40,000	40,000	40,000	40,000
Additional driver salary	£/year/bus		0	0	0	24,000	0	0
Depot overheads	£/year/bus		7,000	7,000	7,000	7,000	7,000	7,000
Infrastructure capex (overall)	£				800,000	800,000	Hydrogen refuelling station costs included in the hydrogen price	
Infrastructure capex (per bus)	£/bus				5,000	5,000		
Infrastructure maintenance (overall)	£/year				0	0		
Infrastructure maintenance (per bus)	£/year/bus				3,000	3,000		
Infrastructure lifetime	years				14	14		

Note: financing costs are not included in this analysis. Other costs (insurance, training, etc. are also excluded). Driver costs based on an assumption of two drivers per bus. Assumed annual mileage per bus is 70,000 km/yr in all cases.

A group of companies is seeking to develop a commercial offer for FC buses based on securing large orders in Scandinavia

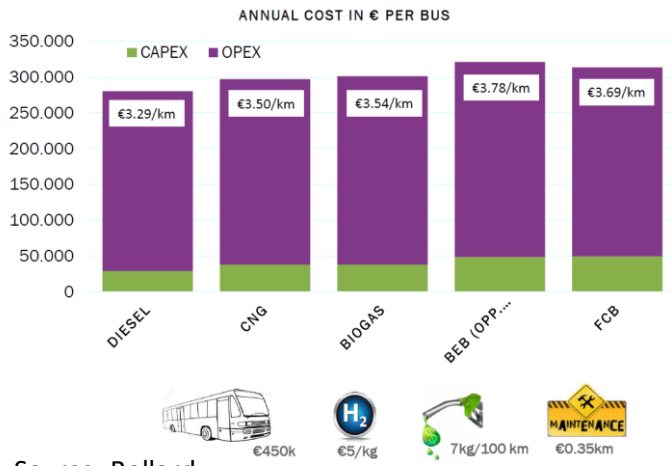
Fuel cell bus market development in Scandinavia

- On September 12th 2017, Solaris, Nel, Hydrogen Valley and Ballard hosted the *FCB17* event.

- This event was significant because of the promise from the hosts to meet a series of price targets for orders **>100 buses**:
  - €450k capital cost per fuel cell bus
  - A maintenance cost of €0.35/km
  - A hydrogen price below €5/kg

- This is the first time prices this low have been declared publicly and according to the promoters, this leads to economic competitiveness vs the battery bus (see graph).

Annual cost analysis by bus powertrain type

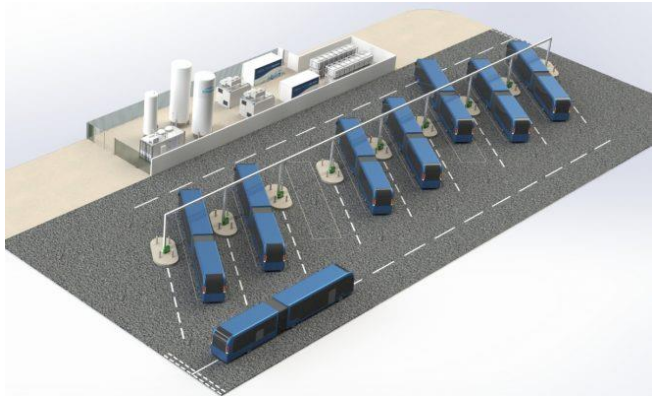


Source: Ballard

For further information see: http://hydrogenvalley.dk/white-paper/

What happens after JIVE? The Commercial Phase from 2020

- A number of the clusters are now looking at how to move to the next, commercial phase beyond the JIVE deployments.
- There are clearly some important ingredients:
  - **Scale of bus demand** – 100's of units per year appear to provide acceptable cost reductions
  - **Scale of demand at a depot**– is required to reduce the price of hydrogen
  - **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

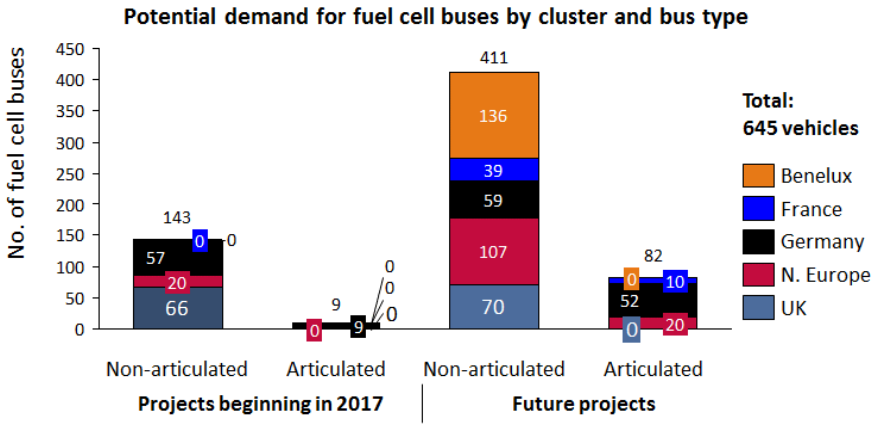
- With this, hydrogen looks capable of being the most affordable and most flexible zero emission option for urban buses, particularly for heavy duty routes (long range, large vehicles etc)

* Source: FCH JU's 2016 Call for Tender: *Procuring a study on Management of a Joint Procurement Strategy for Fuel Cell Buses* (July 2016)

The cluster coordination work has identified demand for hundreds of FC buses in Europe and is leading to progress in reducing costs

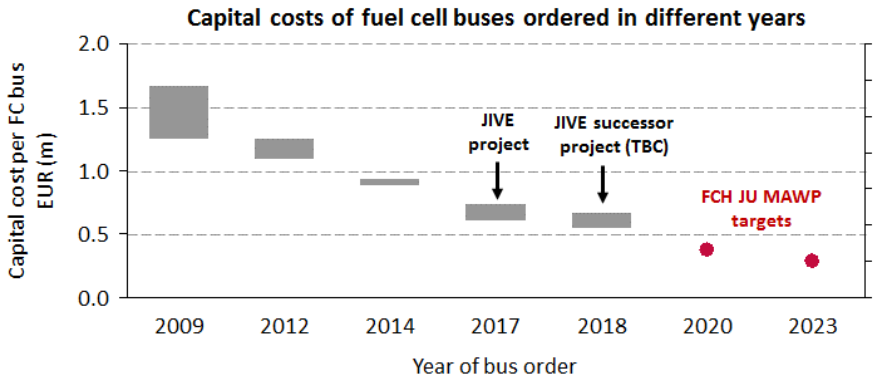
Achievements to date

- ✓ Demand for >600 fuel cell buses identified
- ✓ Initiation of large-scale coordinated deployment projects (JIVE 1 and 2)
- ✓ Procurement exercise launched for many tens of buses in the UK*; similar process underway in Germany
- ✓ Indications of a number of suppliers interested in delivering buses below the €625k FCH JU price target
- ✓ Demand for fuel buses in countries that had not previously engaged with the technology (Denmark, France, etc.)
- ✓ Development of innovative approaches to joint procurement (e.g. new special purpose vehicle in the Netherlands)



Potential demand for FC buses by cluster and bus type

Source: *Strategies for joint procurement of fuel cell buses*, Element Energy et al. for the FCH JU, Figure 9, p.30 (July 2016).



* http://ted.europa.eu/udl?uri=TED:NOTICE:157506-2017:TEXT:EN:HTML&src=0

City / regional representatives are invited to get involved in this initiative by contacting the appropriate cluster coordinator

Cluster coordinators – contacts

Benelux	REBEL Twynstra Gudde	Marc van der Steen, Rebel Marc.vanderSteen@Rebelgroup.com Ellen Lastdrager-van der Woude ela@tg.nl
France & Southern Europe	AFHYPAC – Association française pour l'hydrogène et les piles à combustible Mobilité Hydrogène France	Bertrand Chauvet, on behalf of AFHYPAC bertrand.chauvet@seiya-consulting.com Alex Stewart, on behalf of AFHYPAC alex.stewart@element-energy.co.uk
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The cluster coordinators would welcome the opportunity to work with city / regional representatives on opportunities for FC bus deployment in the context of the *FCH JU Regions* initiative.*

* www.fch.europa.eu/page/about-regions