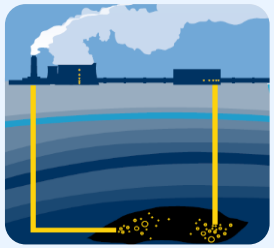








Fuel cell buses in Europe: Latest developments and commercialisation pathway

CTE – US ZEB webinar

July 25th 2017

Element Energy Ltd

michael.dolman@element-energy.co.uk

- **Introduction**
- Context
- FC buses: key developments to date
- Future plans for FC bus deployment
- Conclusions

About Element Energy

Element Energy is a leading low carbon energy consultancy . We apply best-in-class financial, analytical and technical analysis to help our clients intelligently invest and create successful policies, strategies and products.

We operate in three main sectors

Low Carbon Transport

- Electric vehicles
- H_2 vehicles
- Market uptake
- Infrastructure modelling
- Business planning
- Project delivery

Built Environment

- Financial viability
- Master planning
- Building design
- Policy advice
- Regional strategy

Power Generation & storage

- Renewables
- Micro-generation
- CCS
- Techno-economics
- Feasibility studies
- Geographic analysis

We offer three main services

Business analysis

- Technology assessments
- Market growth
- Market share
- Financial modelling
- Commercialisation advice

Strategy and Policy

- Scenario planning
- Techno-economic modelling
- Business planning
- Stakeholder engagement

Engineering

- CFD
- Software tools
- Prototyping
- Installations

- Introduction
- **Context**
- FC buses: key developments to date
- Future plans for FC bus deployment
- Conclusions

Buses are likely to remain a central element of public transport systems in Europe and beyond

"Buses and coaches are an integral part of public transport and travel, and key elements in a sustainable transport system. They ensure inclusive sustainable mobility for all citizens and visitors - in the countryside and urban areas alike - through public transport services customised to mobility needs of the travelling public."

Source: www.busandcoach.travel

Cities across Europe and beyond are facing common challenges:

- **Increasing urbanisation & congestion** – growing demand for transport services
- **Environmental challenges** – air quality, GHG emissions
- **Economic constraints** – providing affordable, reliable, high quality services with limited budgets

Electrification is currently the only viable option for delivering zero emission buses, with two principal options:

1) Battery electric buses
2) Fuel cell electric buses

Source (photos): Alexander Dennis, CHIC project.

Cities are beginning to plan to phase out diesel buses – e.g. London's draft Transport Strategy proposes 100% ZE bus purchases from 2025

Mayor of London's Transport Strategy (draft) – key policies for buses

From 2020

- All new single deck buses to be zero emission
- All single deck buses in central London to be zero emission

From 2025

- All new single and double deck buses to be zero emission

From 2037

- 100% of TfL's buses to be zero emission (electric or hydrogen)

		NOW	2020	2025	2030	2035	2037
Bus procurement and retrofit		Retrofit of existing double decks to Euro VI standards TfL will buy only hybrid double decks	TfL will buy only electric or hydrogen single decks	TfL will buy only electric or hydrogen double decks			
Bus fleet in central London			All single decks electric or hydrogen				All TfL buses electric or hydrogen
			All double decks Euro VI and hybrid			80% of double decks electric or hydrogen	
Bus fleet in inner and outer London				50% of single decks electric or hydrogen	90% of single decks electric or hydrogen	All single decks electric or hydrogen	
			All double decks meet Euro VI standard as a minimum	More than 85% of double decks hybrid, electric or hydrogen	60% of double decks hybrid; 40% electric or hydrogen	20% of double decks hybrid; 80% electric or hydrogen	

Source: *Mayor of London's Transport Strategy – draft for public consultation*, Figure 13, p.97 (June 2017).

- Introduction
- Context
- **FC buses: key developments to date**
- Future plans for FC bus deployment
- Conclusions

Why choose fuel cell buses?

High daily range

300+ km without refuelling

Operational flexibility

…no need for new street infrastructure, rapid refuelling (<10 min)

Zero tailpipe emissions

Only water emitted and CO_2 emissions savings – linked to hydrogen production source

Comfort for passengers and drivers

…due to reduced noise levels and smooth driving experience

Collaboration

A European network of frontrunners in place willing to share their expertise

A concrete answer to ambitious policy targets set for transport decarbonisation

Source: CHIC Emerging Conclusions

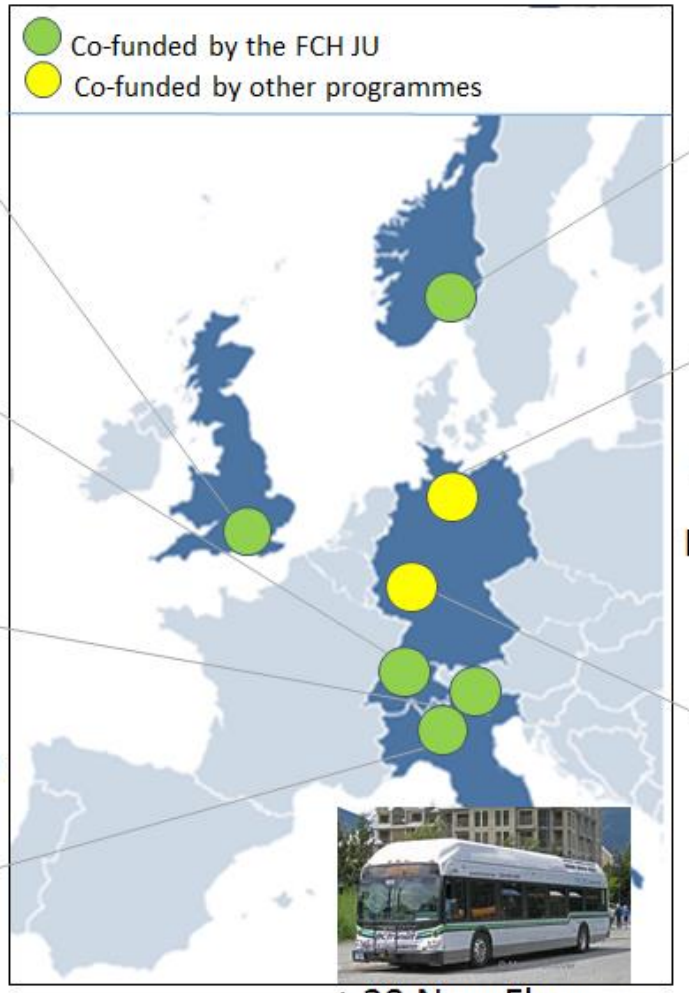
CHIC delivered 56 fuel cell buses in eight cities from six different OEMs

London - 8 Wrightbus

Aargau - 5 EvoBus

Bozen/Bolzano - 5 EvoBus

Milan - 3 EvoBus



+ 4 ICE H2 buses in **Berlin**

+ 20 New Flyer – **Whistler** (Canada)

Oslo - 5 Van Hool

4 EvoBus

Hamburg

2 Solaris

2 APTS/ Phileas

Cologne

2 Van Hool

Source: CHIC Emerging Conclusions

CHIC conclusions & next steps

CHIC project conclusions

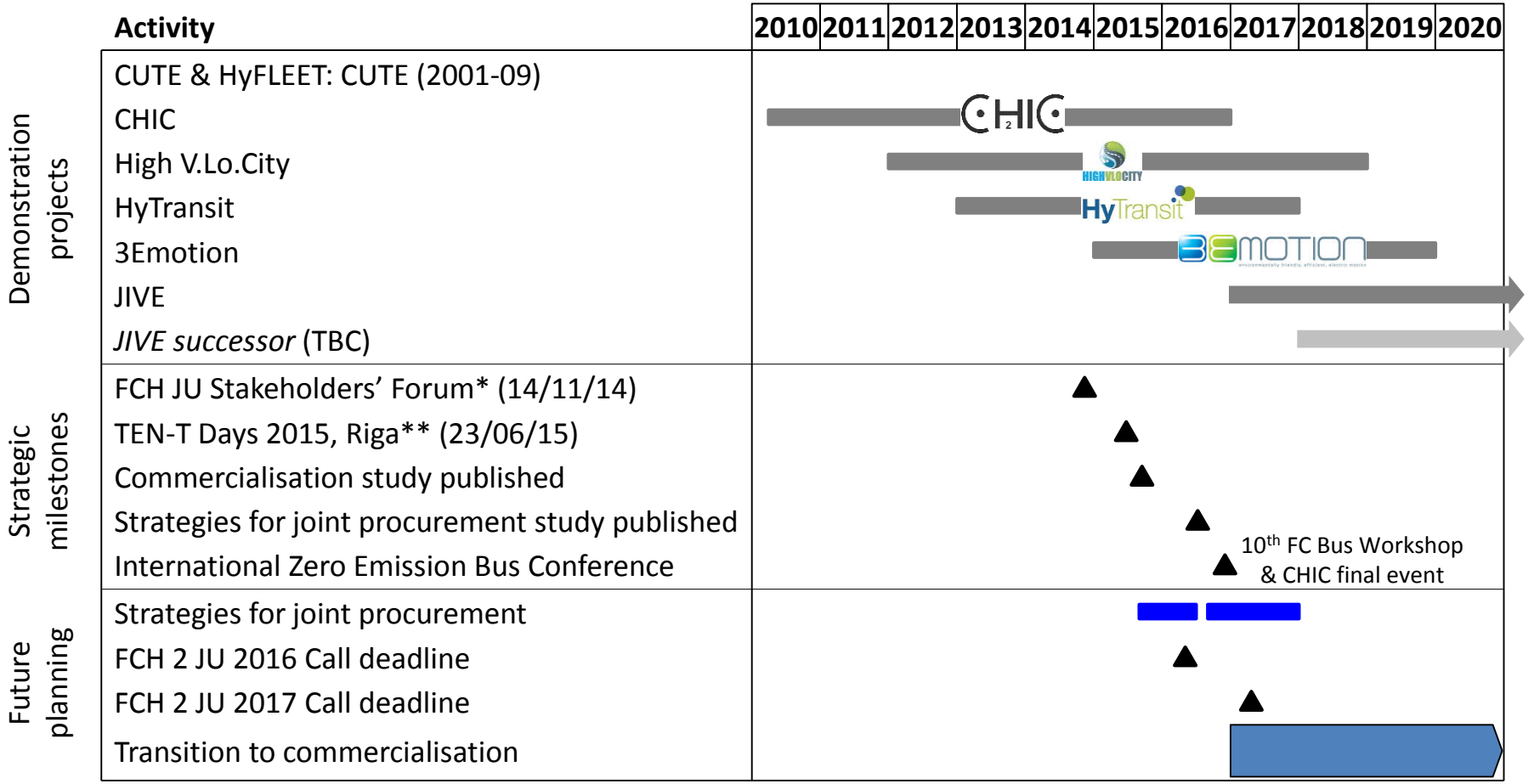
Hydrogen fuel cell buses can offer:

- ✓ **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

Other demonstration projects put the combined fleet of buses on European roads at an estimated 80 buses by the end of this year

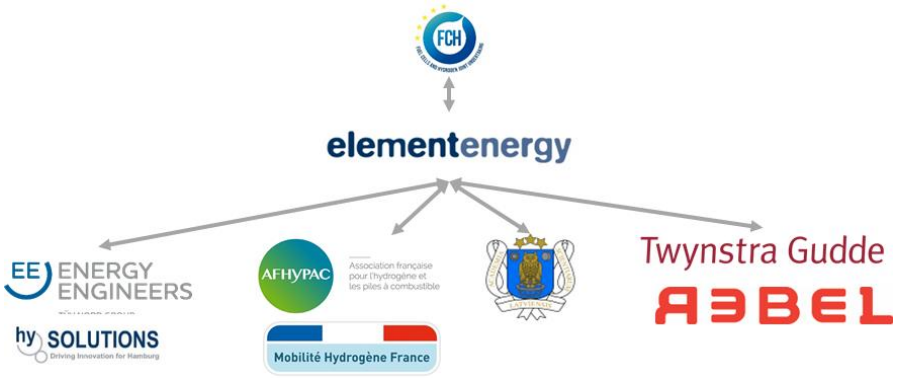


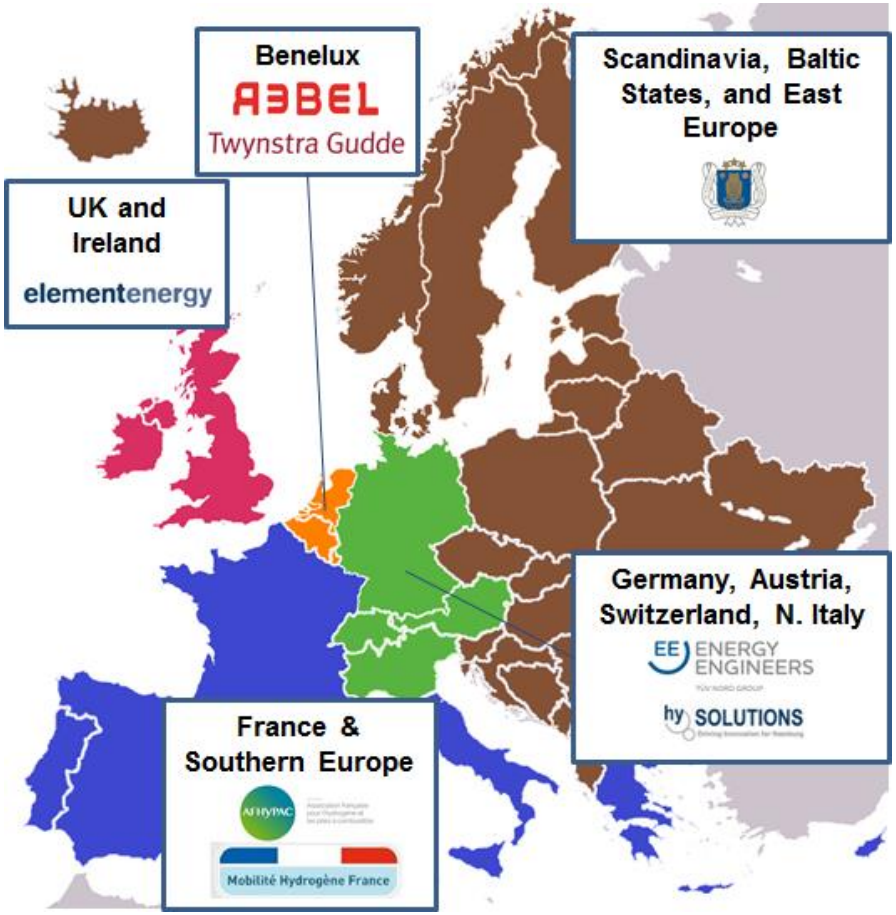
* Plans for commercialisation of FC buses confirmed in joint letter from five European bus OEMs at the FCH JU's Stakeholders' Forum, Brussels (14/11/14).

** Declarations from innovative first buyers of five national clusters and from innovative producers signalling commitment to commercialising FC buses. TEN-T Days 2015, Riga (23/06/15).

- Introduction
- Context
- FC buses: key developments to date
- **Future plans for FC bus deployment**
- Conclusions

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

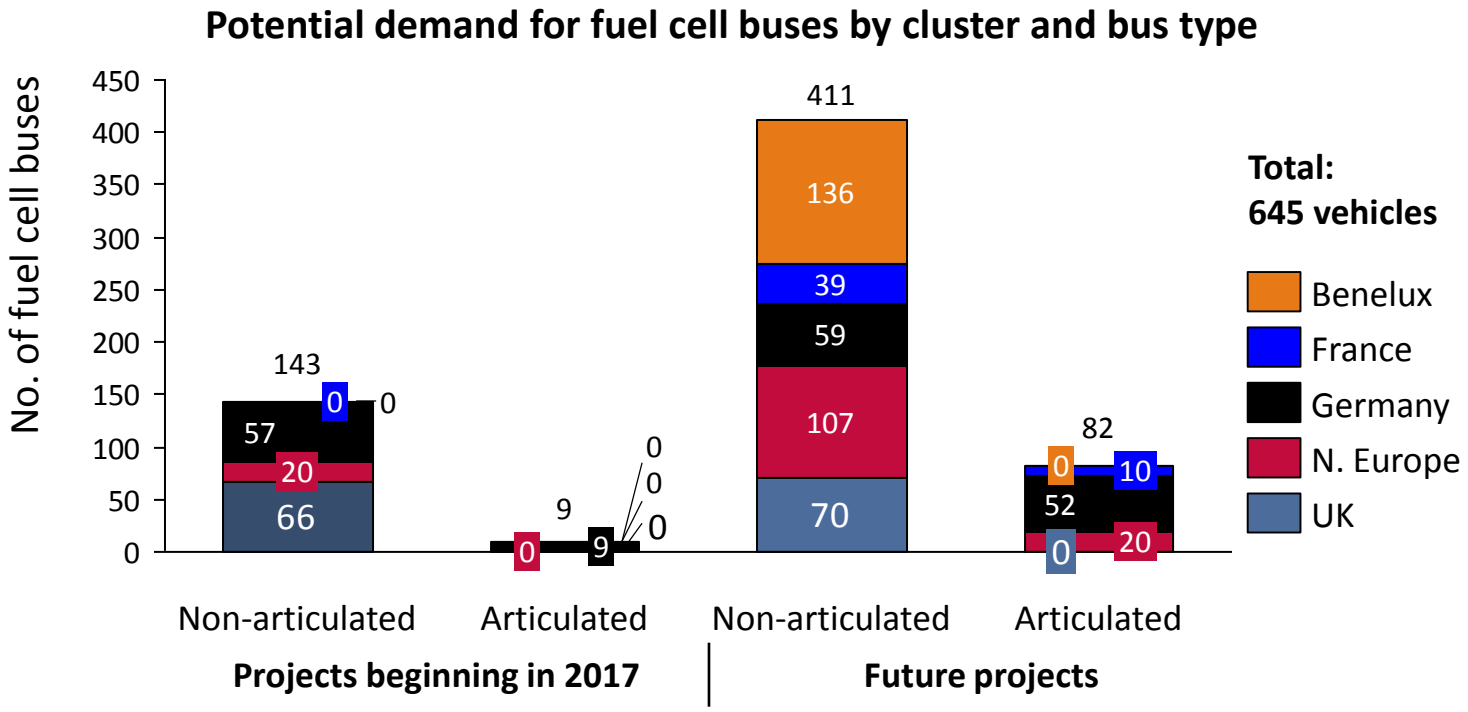




Strategies for joint procurement of fuel cell buses (July 2016)

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

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. 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.

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

The FCH JU has allocated €57m of funding to support large-scale fuel cell bus demonstrations in its two most recent calls

FCH JU 2016 call (topic 1.9)

Selected criteria

- At least **100 buses** across the project, including at least three locations with 20+ buses.
- A minimum of **10 buses per deployment location** within the project.
- Availability >90% on a fleet basis after an initial 6 month ramp-up phase.
- Target maximum cost of buses: **€650k** (12m / 13.5m) / €1m (articulated) (baseline spec.).
- Funding available: **€32m**.

Joint Initiative for hydrogen Vehicles across Europe (JIVE) project

FCH JU 2017 call (topic 1.5)

Selected criteria

- At least **125 buses** expected.
- At least three cities with 20+ buses.
- Up to five cities may deploy fleets of 5+ buses – remainder must have 10+ buses.
- Average monthly fleet availability >90% after 6 months.
- **€625k** per bus capital cost limit (c.12m bus).
- Funding available: **€25m**.

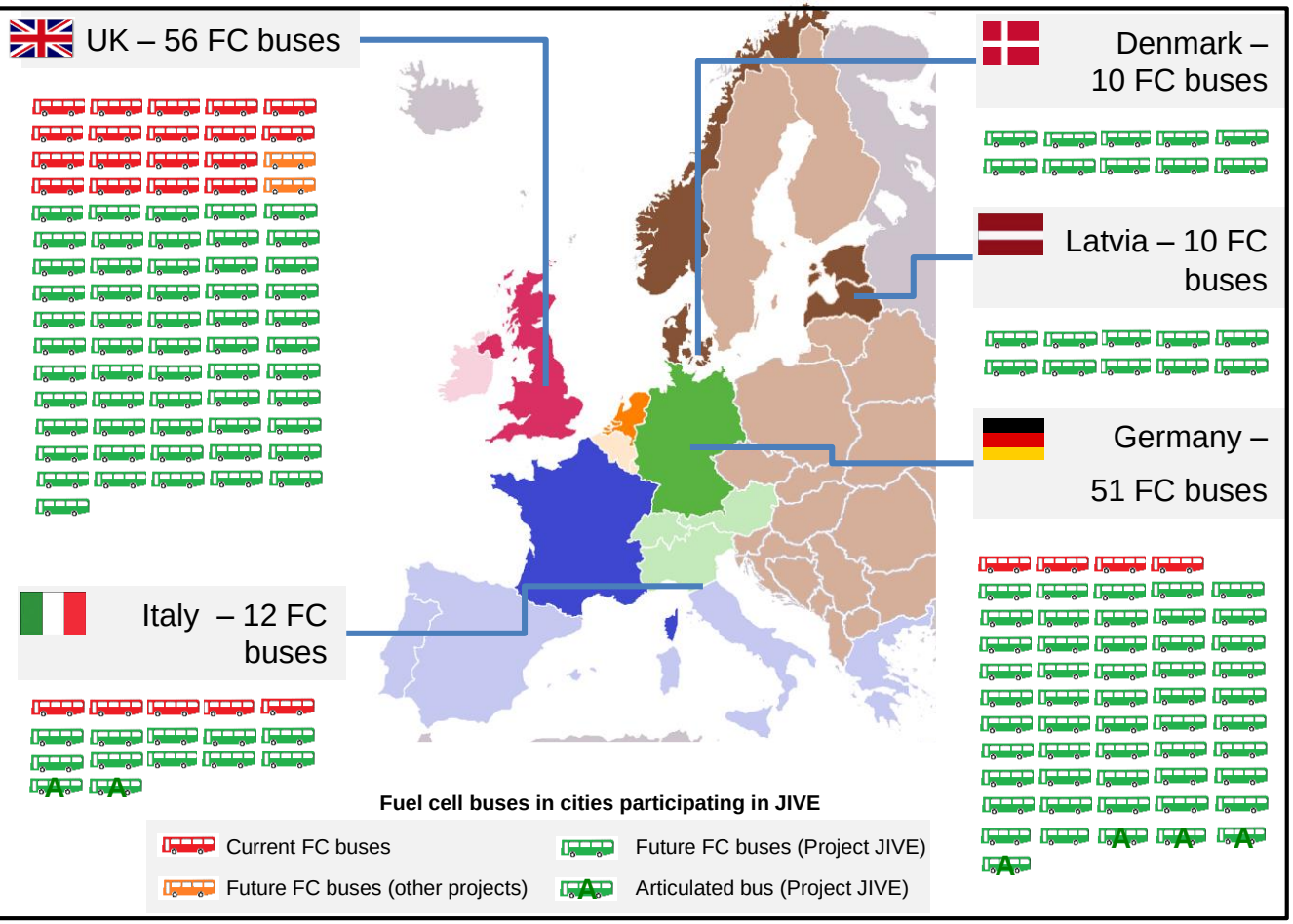
Successor to JIVE project – anticipated start date: early 2018 (TBC)

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



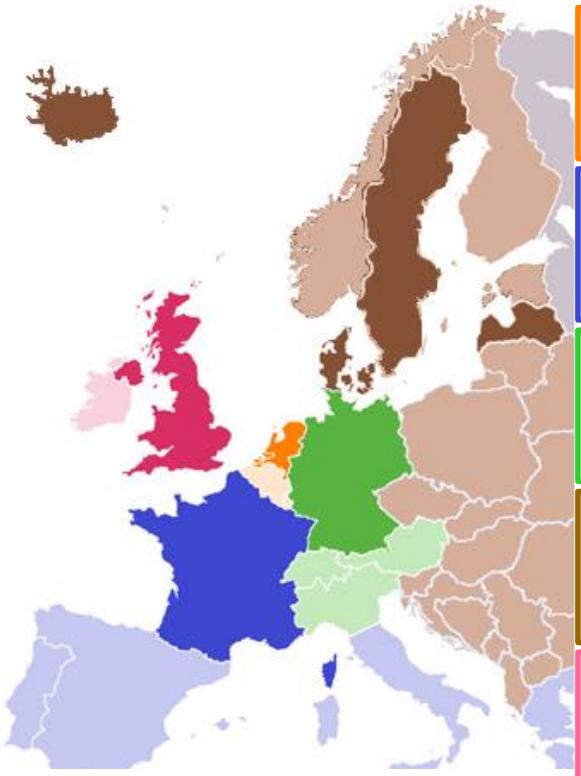
JIVE began in January 2017 and will be a six year project

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



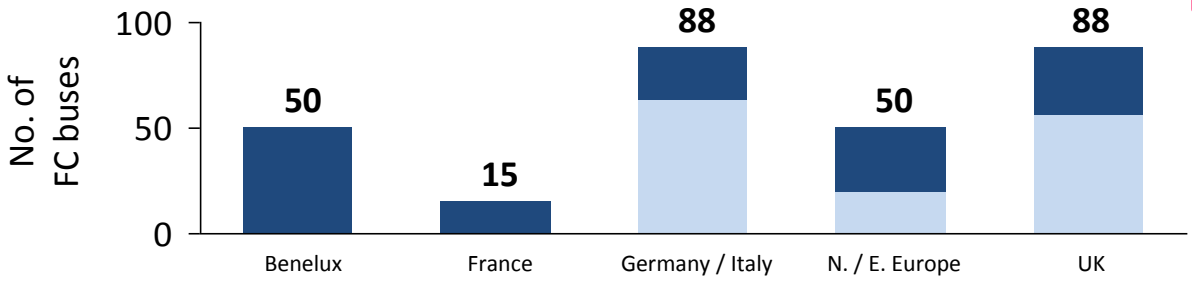
Benelux Cluster (50 FC buses)

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

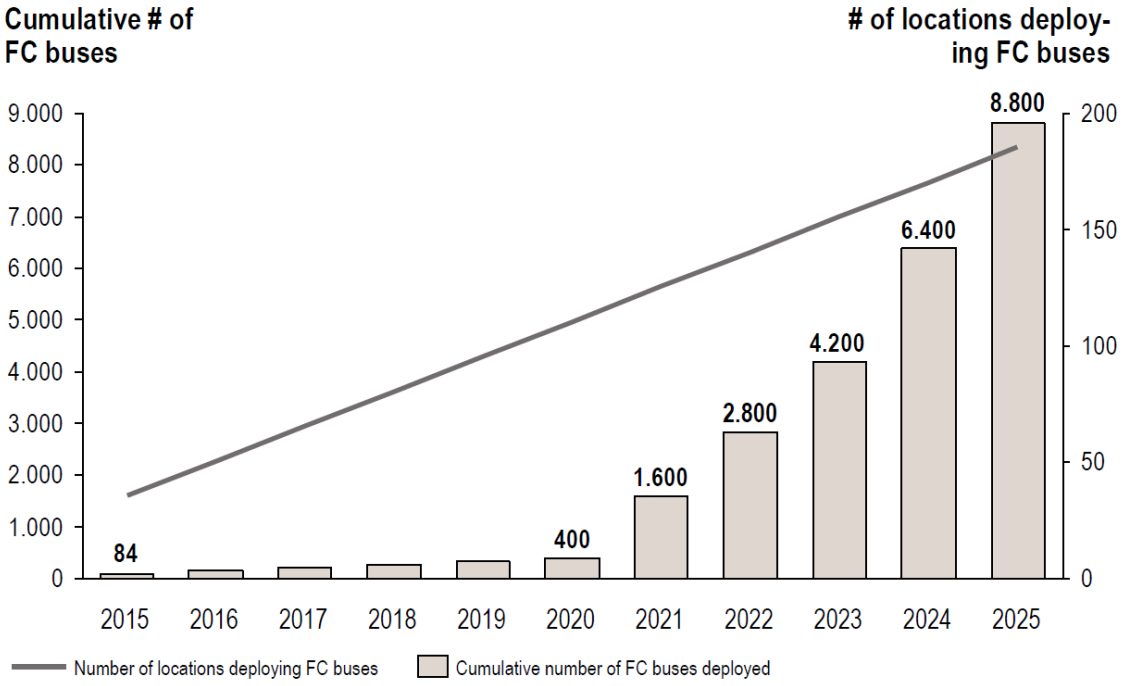
JIVE

JIVE 2

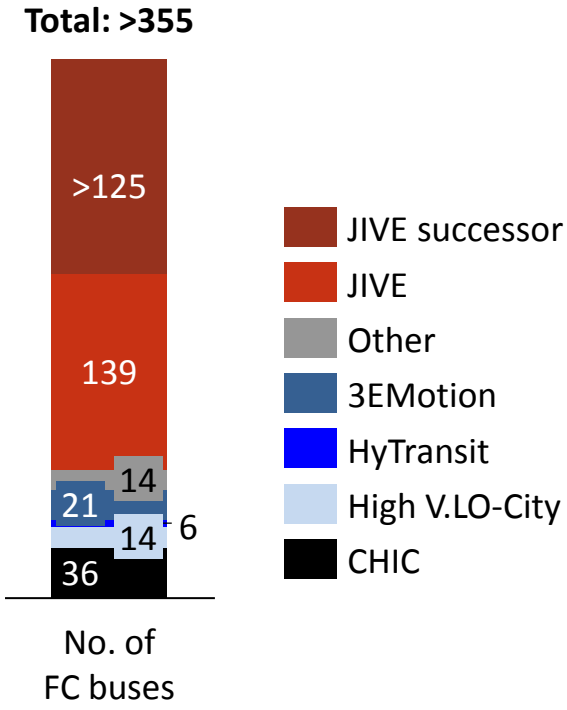
"JIVE 2" builds on the objectives of the "JIVE" project, which began in January 2017. See www.fch.europa.eu/news/launch-project-jive-large-scale-deployment-fuel-cell-buses-europe

The fuel cell bus commercialisation coalition developed a ramp-up scenario that suggests c.400 FC buses deployed in Europe by 2020

Ramp-up scenario for FC buses in Europe



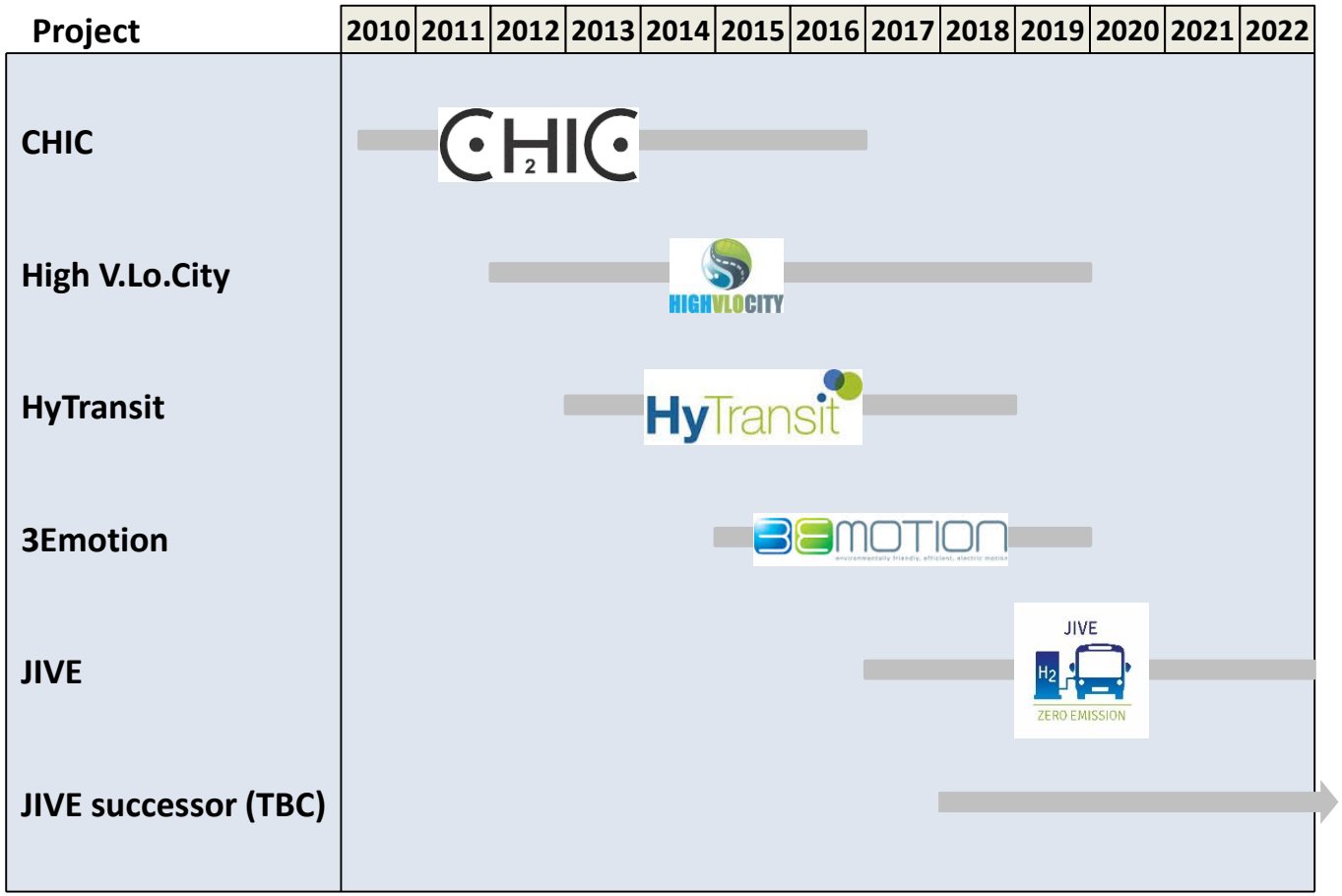
Number of fuel cell buses in Europe deployed / planned by project



Source: *Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe*, Figure 29, p.48, Roland Berger for the FCH JU (2015).

Existing / planned projects will deliver 350–400 FC buses by the early 2020s – further scale-up will be required to deliver the vision of the *European ramp up* scenario.

With JIVE now underway, we are beginning to plan for continued deployment of FC buses beyond the subsidised phase



EU-funded projects have demonstrated over 90 FC buses in 16 different cities.

Large-scale demonstrations from 2017/18.

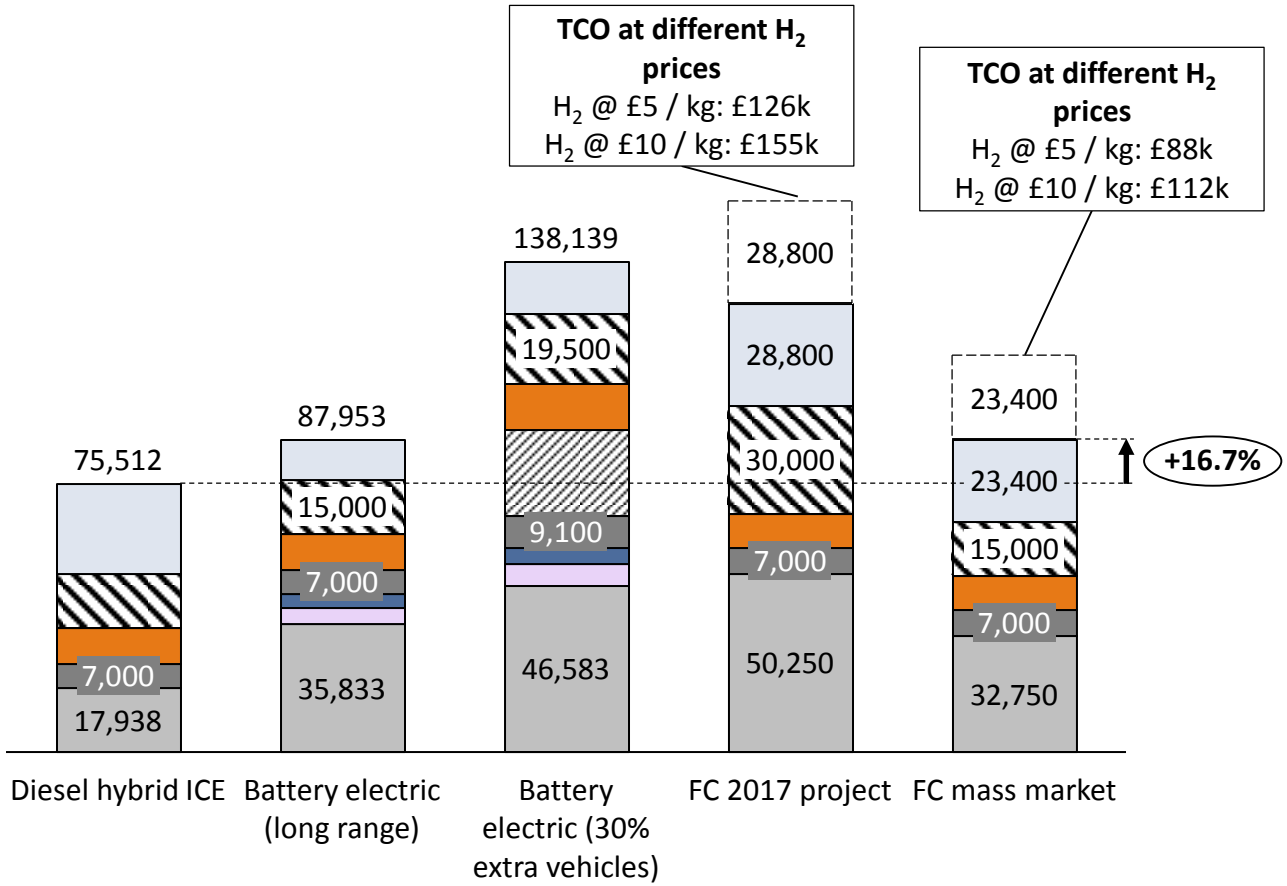
- The FC bus sector cannot rely on subsidies indefinitely…
- We are therefore formulating plans for further uptake on a commercial basis in the early 2020s.

http://chic-project.eu/; http://highvlocity.eu/; www.fch.europa.eu/project/european-hydrogen-transit-buses-Scotland; http://www.3emotion.eu/.

Single decker FC buses can come at similar premiums compared to diesel ICE vehicles, and could outcompete electric options

Single decker bus annuitized ownership cost analysis

GBP per year – annuitized over 12 year lifetime



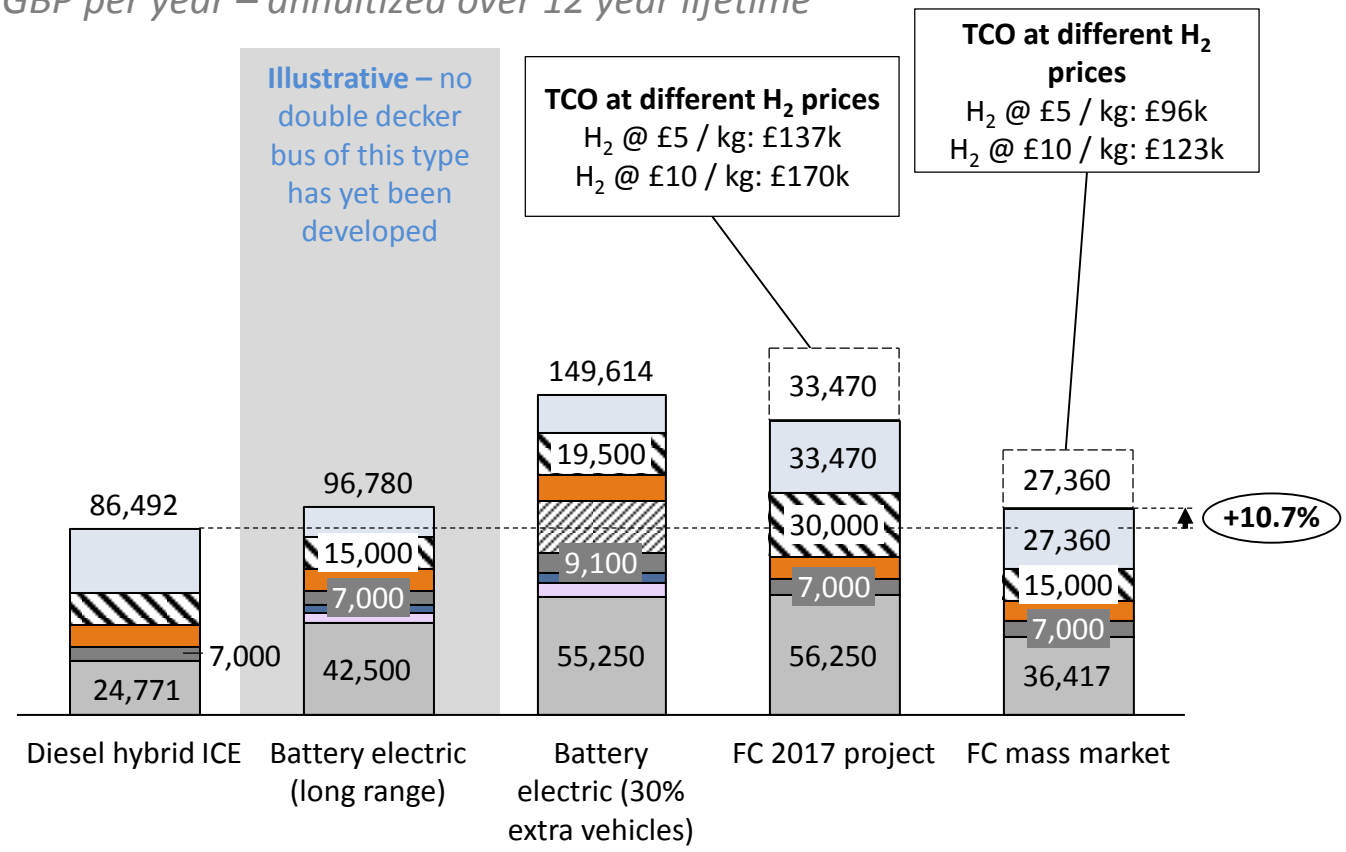
Note: 30% more buses are needed to compensate for the extra charging time required during the day due to the limited range of battery-electric buses.

Source: Element Energy.

At mass market scales, with fuel costs of ~£5/kg, cost projections suggest that FC double decker buses will come at a cost premium of 10–20%

Double decker bus annuitized ownership cost analysis

GBP per year – annuitized over 12 year lifetime



- Additional H2 cost (@£10 / kg)
- Fuel costs
- Bus drivetrain maintenance costs
- Bus regular maintenance costs
- Additional bus driver costs
- Depot overhead costs
- Infrastructure capex
- Infrastructure maintenance costs
- Bus capex

Note: 30% more buses are needed to compensate for the extra charging time required during the day due to the limited range of battery-electric buses.

The NewBusFuel project examined options for large-scale hydrogen refuelling at bus depots

NewBusFuel

1 Aberdeen
- Linde
- Aberdeen City Council

9 Oslo/Akershus
- HYOP
- Akershus City Council
- Kunnskapsbyen Lillestrom Forening

2 Birmingham
- ITM Power
- Birmingham City Council

11 Riga
- Industry role to be tendered
- Riga Satiksme

7 London
- Air Products
- London Bus Services Limited

5 Hamburg 1
- Vattenfall Innovation
- Hamburger Hochbahn
- Siemens

4 De Lijn
- Linde
- De Lijn

6 Hamburg 2
- Air Products
- Hamburger Hochbahn

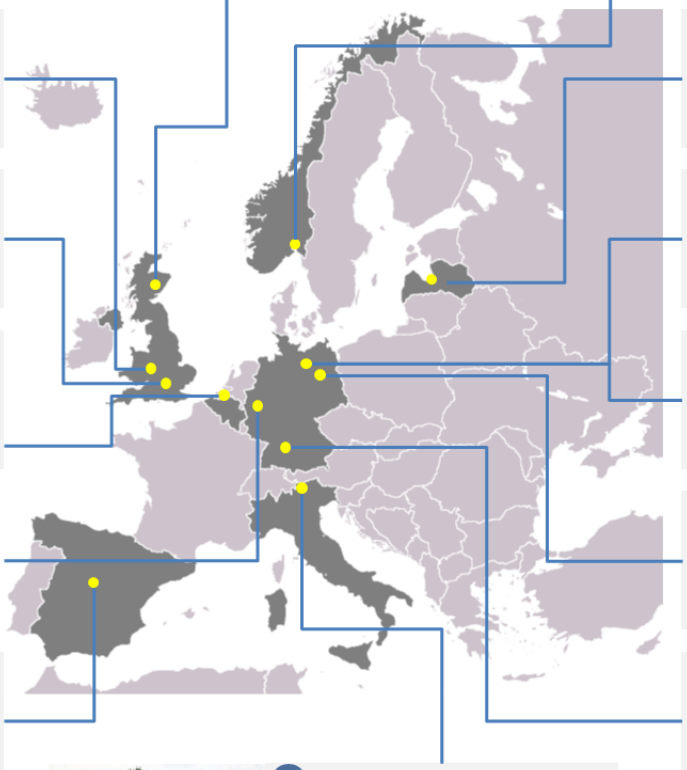
13 Wuppertal
- Hydrogenics
- Wuppertaler Stadtwerke

10 Potsdam
- McPhy Energy
- ViP Potsdam
- H2 Logic

8 Madrid
- Abengoa Hidrógeno
- Empresa Municipal de Transportes de Madrid

12 Stuttgart
- Siemens
- Stuttgarter Strassenbahnen

3 Bolzano
- Ingenieurbüro Bergmeister
- Institut für Innovative Technologien Bozen Konsortial
- Siemens, Linde



Industrial lead
Operator lead
Other industrial

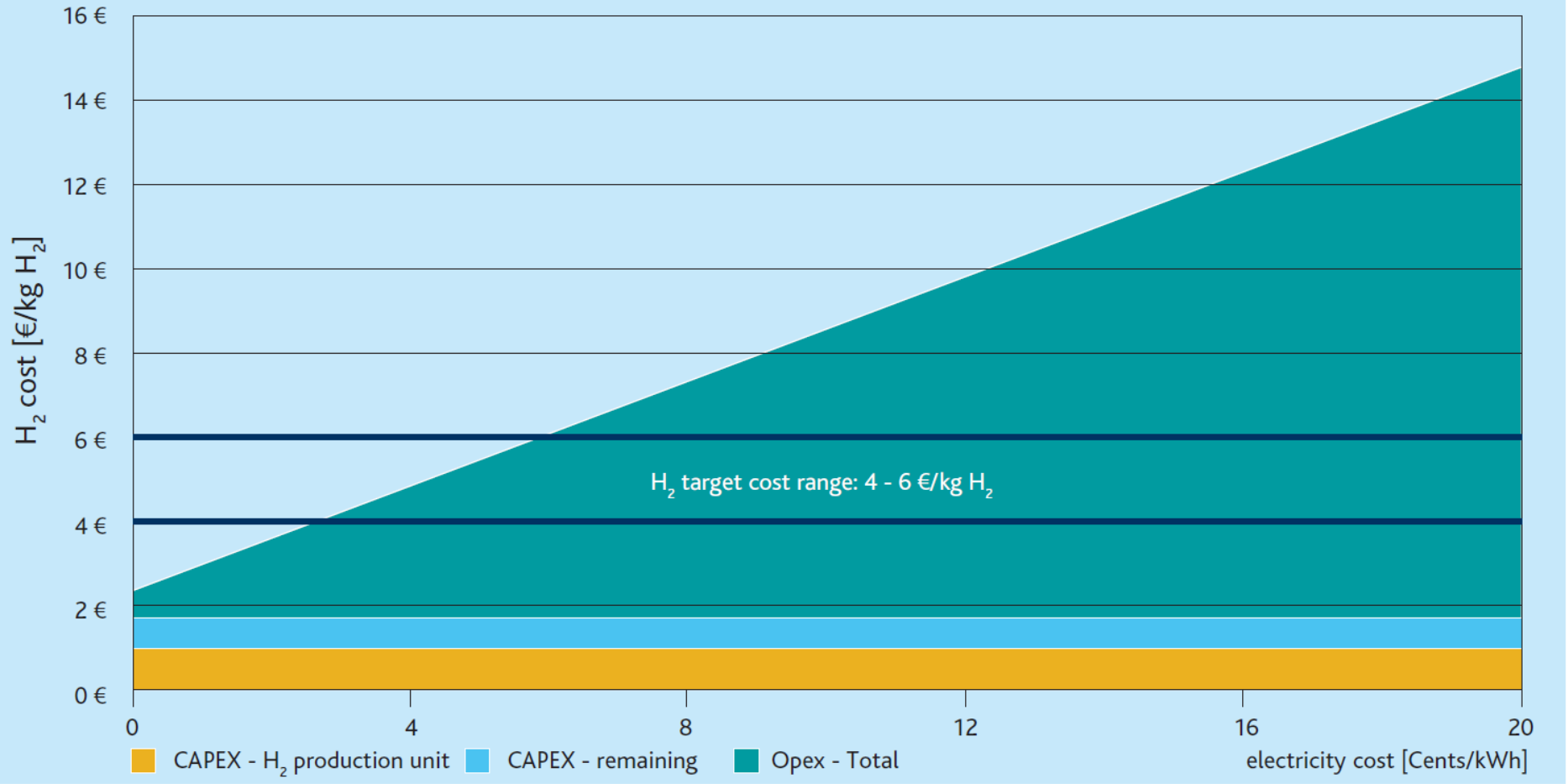
Inter-study partners: Element Energy, thinkstep

Source: NewBusFuel project – see http://newbusfuel.eu/publications/

Accessing low cost (renewable) energy supplies will be key to generating cost-effective hydrogen

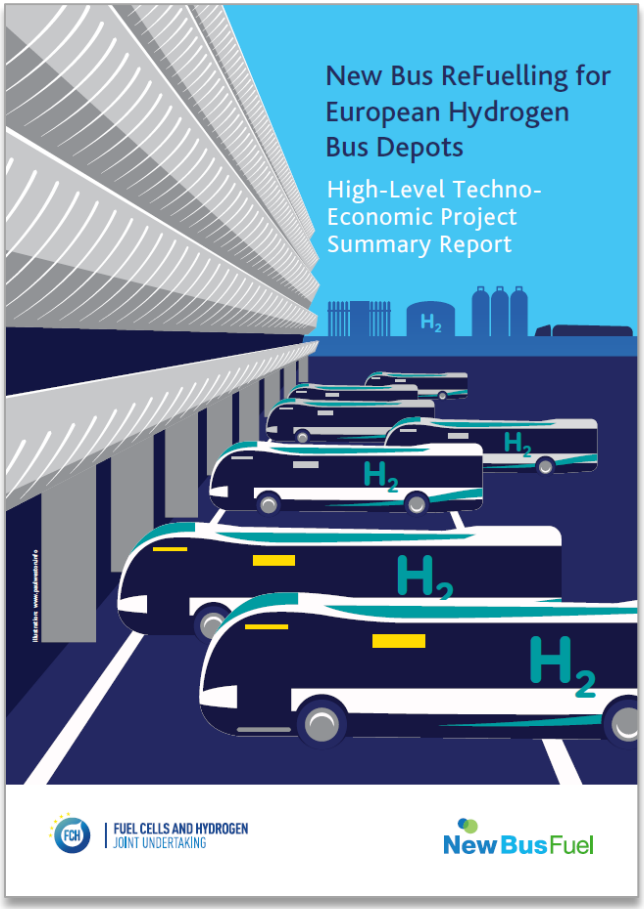
NewBusFuel

Overall H_2 costs in €/kg H_2 for the generic HRS example with 3,000 kg H_2/d using on-site electrolysis



Source: NewBusFuel project – see http://newbusfuel.eu/publications/

The main NewBusFuel project results are available as two reports: a techno-economic summary and a guidance document



The two main project reports are intended to assist procurement activities for bus operators with no prior experience of hydrogen refuelling technologies

- Introduction
- Context
- FC buses: key developments to date
- Future plans for FC bus deployment
- **Conclusions**

Hydrogen fuel cell buses in Europe – conclusions

- The technology has been **demonstrated in a range of real-world environments** – millions of kilometres & thousands of refuelling events to date

- Key challenges to further adoption:
  - Improved availability of vehicles – to be achieved via the ongoing demonstration projects
  - Cost reductions – vehicles and hydrogen fuel

- Procurement plans are in place for approximately 300 buses before 2020

- A commercialisation process is underway that could lead to competitive fuel cell buses in the 2020s

- *"The FCH JU and the FC bus coalition have the strong conviction that a deployment of around 1,000 fuel cell electric buses will push costs to an acceptable level (close to hybrid buses and no or little need of subsidy)"**

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

transdev
MOBILITY INSPIRED BY YOU

Electric bus operations at Transdev

Actual – in preparation - engagements
July 2017.

Marc VANHOUTTE
Bus Fleet Director
Solution Manager e-mobility

The way to electrification

Traditional technologies

Buses with combustion engines using fossil fuel

diesel

CNG

Hybrid buses

Hybrid buses with propulsion partially with a combustion engine and partially with an electric motor

Parallel hybrid

Serial hybrid

Full electric drive with electric power generated by a combustion engine

Extending the range of electric propulsion with hybrid plug-in

Full electric buses

ZERO tail pipe EMISSION

Trolley buses

Conventional trolley
Trolley hybrid

Battery electric buses

Overnight charging electric bus

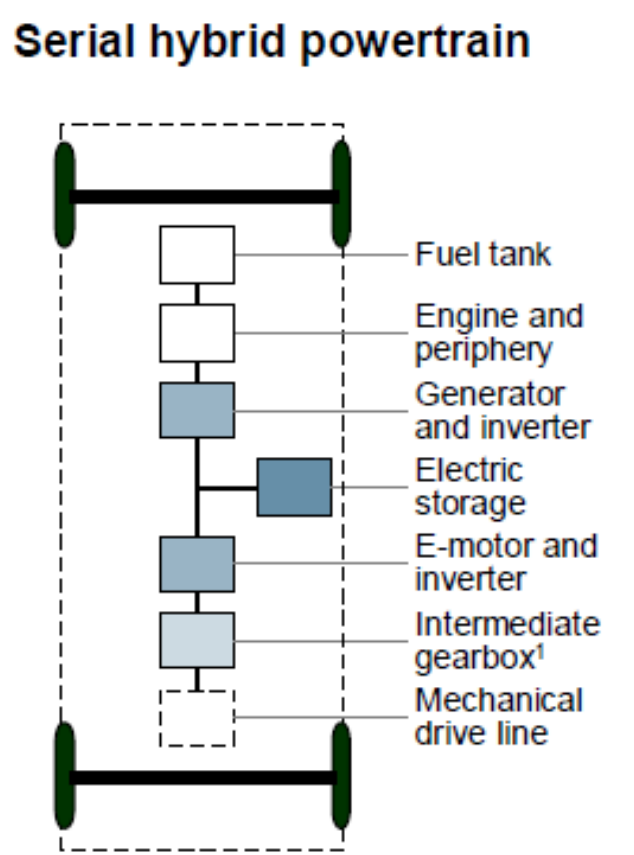
Fuel cell buses

Hydrogen for on-board electricity regeneration

Opportunity charging electric bus

Charging at end stations and/or at bus stops

Hybrid electric buses



The bus is driven by the electromotor, the combustion engine is only used for charging the electric storage system. Electric autonomy depends on the electric storage capacity and the combustion engine capability to charge the batteries.

Advantages

No gearbox needed, sometimes a transfer-gearbox (one reduction)

Disadvantages

Only driven by the electric driveline, no back up.

Plug-In hybrid electric buses

A **Hybrid bus** with two or more power sources in the drivetrain.

A **combustion engine** can be used for driving the bus (parallel hybrid) or to charge the batteries (serial hybrid), in addition to the **electric drivetrain**.

Larger **electricity storage capacity** than in “Non plug-in hybrids”.

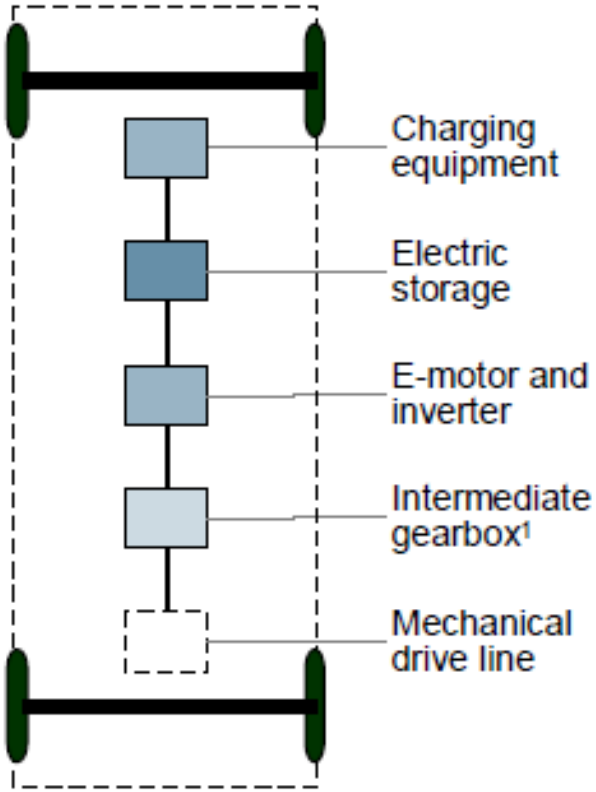
Energy storage devices are **charged from the grid** like **“Overnight charging”** full electric buses or during several bus stops like **“Opportunity charging”** full electric buses.

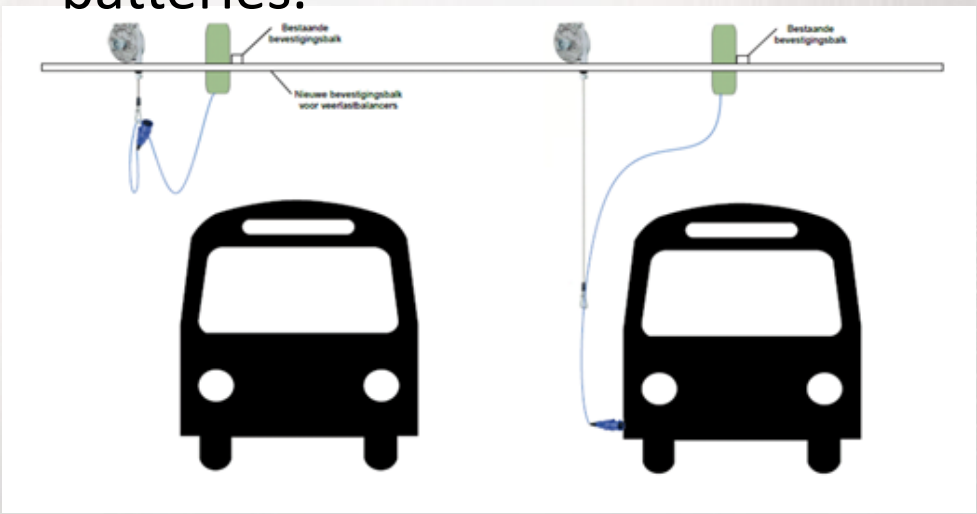
Electric buses

Purely electric drive

- Large battery capacity > 200 kWh.
- Li-ion, LiFePO4 battery technologies.
- Medium autonomy: 100 – 250 km.
- Batteries are charged from the grid only while stationary at the depot.
- Limited number of passengers because of the weight of the batteries.

Overnight-charging powertrain

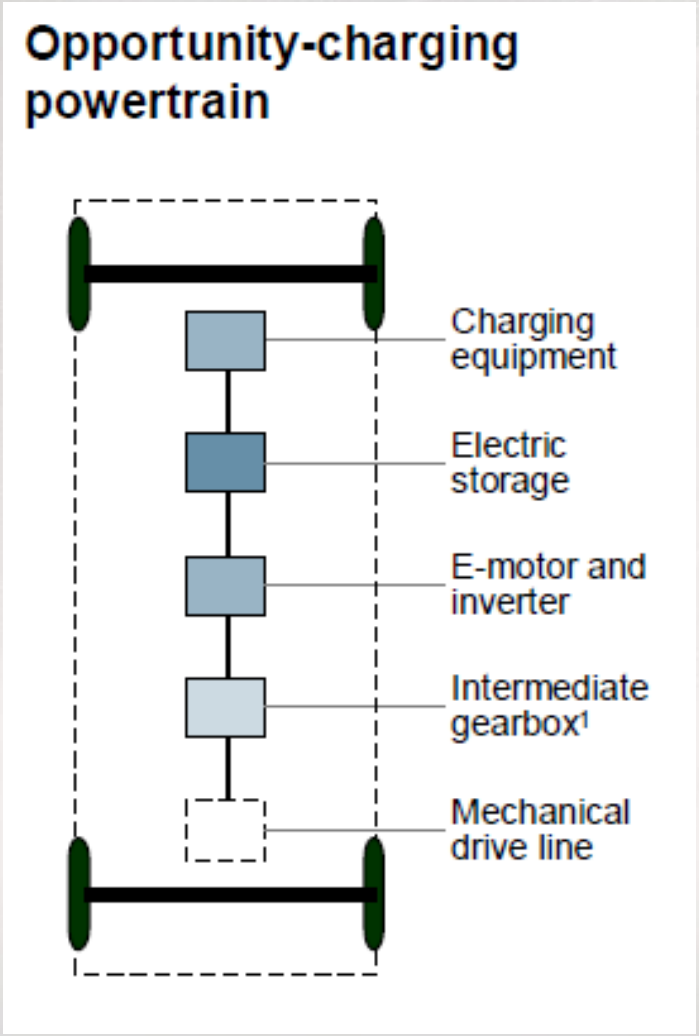




Electric buses

Purely electric drive

- Medium battery capacity: 40-60 kWh.
- Li-ion, LiFePO4 battery technologies.
- Short autonomy: < 100 km.
- Batteries are charged from the grid only while stationary at bus terminals or at intermediate bus stops by inductive or conductive charging.



E-BUS CHARGING

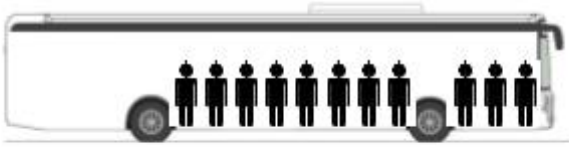
SRS principle

Charging systems

- Cable and plug
- Pantograph
- Mechanical device
- Induction

Slow charging (High Energy)

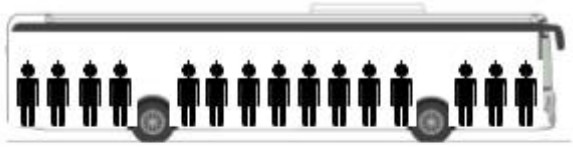
Charging time = **HOURS**



ONLY SLOW

Fast charging (High Power)

Charging time = **MINUTES**



SLOW & FAST

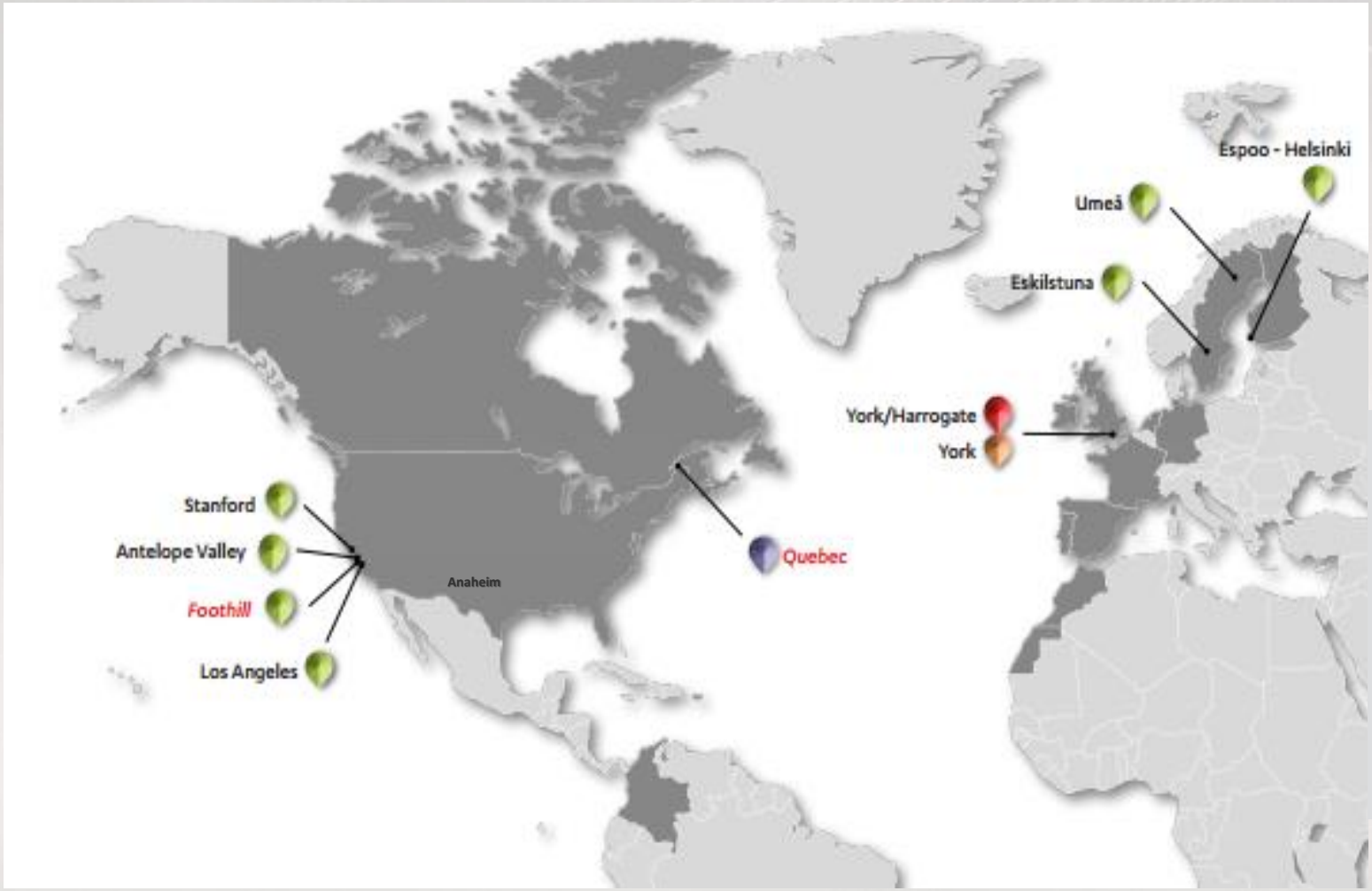
Opportunity charging at Transdev

Left: conductive opportunity charging with the use of an arm.

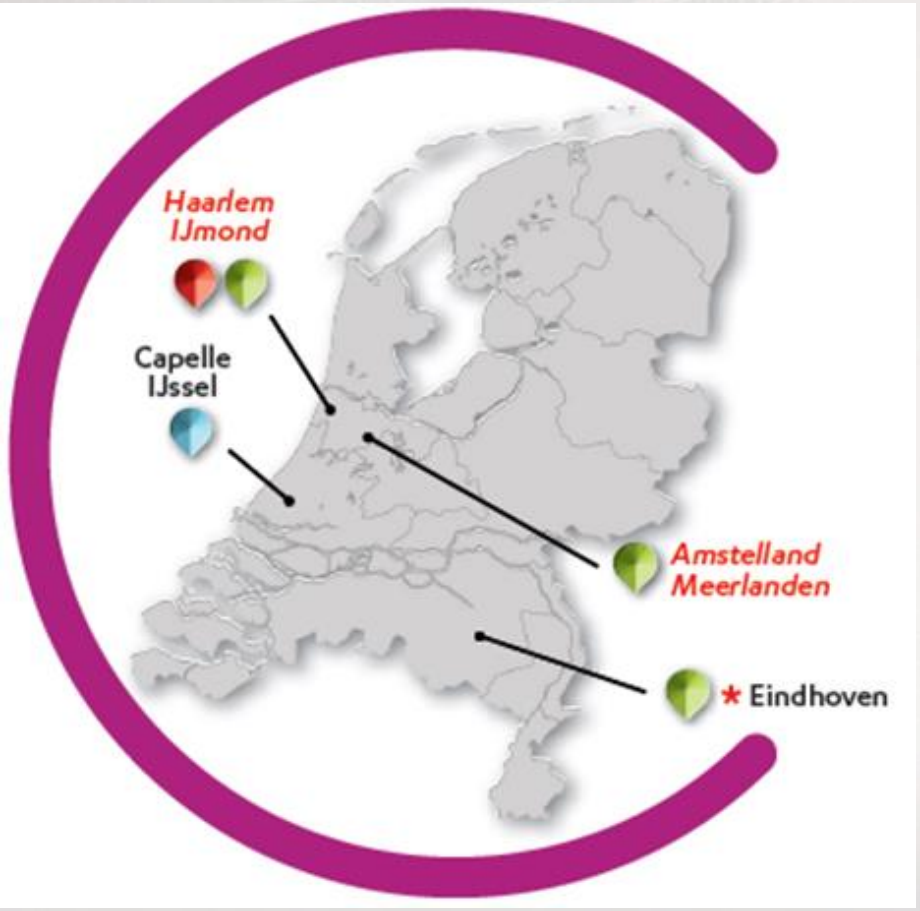
Below left: conductive opportunity charging by means of a pantograph placed on the bus

Below right: pantograph connected with the contact hood of the charger.

Transdev Electric bus operations



Transdev Electric Bus operations France – The Netherlands



Electric buses in operations at Transdev

Battery buses with overnight charging

Mini and Midi buses					80
BYD	8 – 12 m	United States:	31		
		Sweden:	12	total	43
BYD	18 m	United States :			1
HYBRICON	12 m	Sweden:			10
EBUSCO	12 m	France (Argenteuil)			1
LINKKER	12 m	Finland:			1
Autobus Lion	School bus	Canada:			3
Magtec	double deck bus	United Kingdom			1
			total		**140**

Electric buses in operation at Transdev

Battery buses with opportunity charging

VDL	18 m	The Netherlands:	43

Other type of electric driven buses
Hydrogen buses

VDL	18 m H2 – electric	The Netherlands	2
		total	**45**
		grand total	**185**

Additional electric buses in operation before the end of 2017

Battery buses with overnight charging

BYD	8 – 12 m	United States:	23		
		The Netherlands:	8	total	31
BYD	18 m	United States :			12
BYD	14 m	United States :			5
PROTERRA	12 m	United States :			13
VDL	Midi	Pays Bas:			8
EBUSCO	12 m	France (Argenteuil)			8
BOLLORE	12 m	France (Aubervilliers):			5
IRIZAR	12 m	France (Le Havre):			3
Magtec	double deck bus	United Kingdom:			5
			total		**90**

Additional electric buses in operation before the end of 2017

Battery buses with opportunity charging

VDL	18 m	Pays Bas:	100

These buses will be put is operation in December and will run on two different services with approximately 130 to 150,000 km's (80 to93,000 miles) on a yearly basis.

Other type of electric driven buses

Hydrogen buses

VDL	18 m H2 – electric	The Netherlands	4
		Total:	**104**

Transdev electric bus fleet at end 2017: 379 units

Development of an e-bus operation

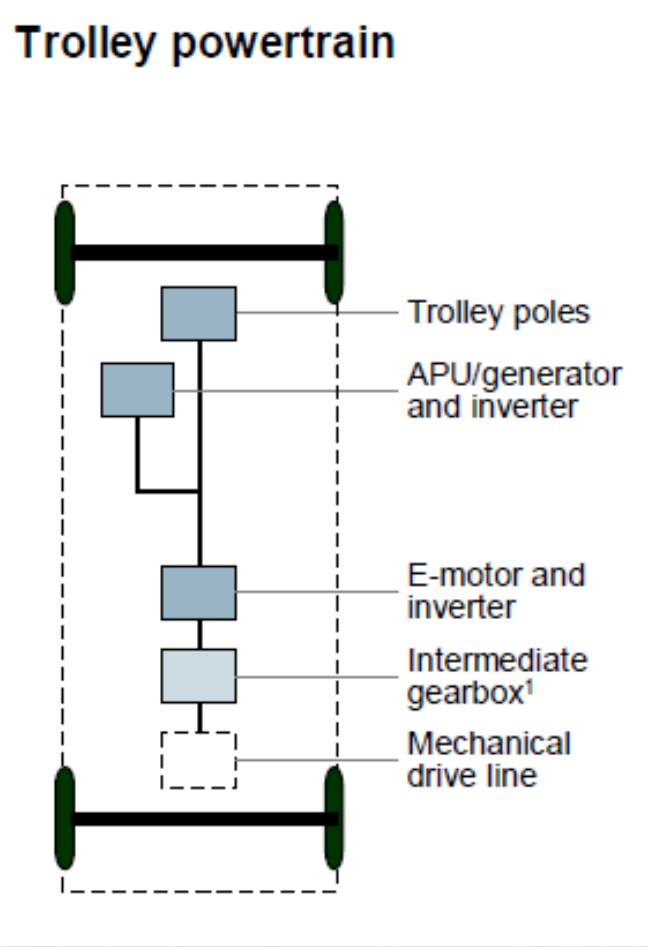
- ***What are the constraints with an e-bus operation?***

- Can we still run the same time table? What are the constraints with the development of a new time table
- How do we have to specify the e-buses?

  "***Battery size***"
- How many extra buses do we need compared with a diesel fleet?
- How and where will we recharge the buses?

  "***Choice of technology and charging infrastructure".***
- What size of energy supply would we need and how controlling the cost of using the energy?

Electric buses



Electric Energy is taken from overhead wires, over spring-loaded trolley poles.

A small combustion engine is sometimes installed for emergency reasons or for crossing wireless sections.

Advantage

Unlimited autonomy with the overhead-wires network.

Disadvantage

Overhead wire network infrastructure.

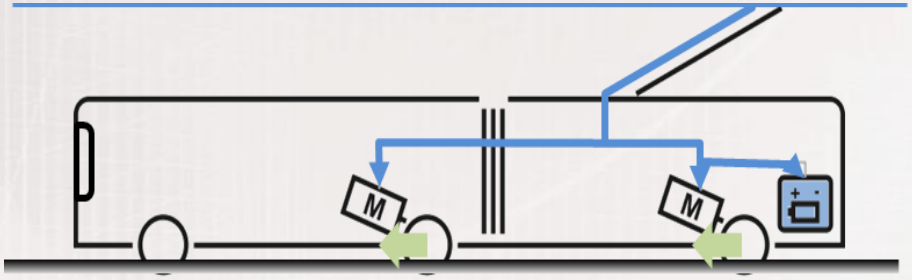
Electric buses

Trolley Bus - Connexxion – Transdev NL - Arnhem

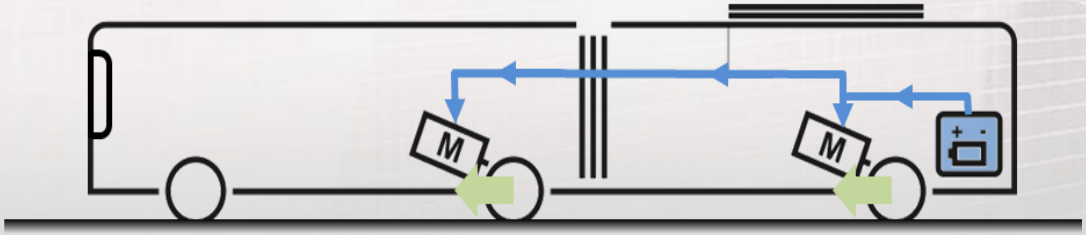
Hybrid Trolley

IMC: In Motion Charging

Driving and charging at the overhead line



Driving on battery power



Hybrid Trolley

transdev
MOBILITY INSPIRED BY YOU

connexxion
Hermes

Zuid – Oost Brabant Concession
Hermes – Cxx 12/2016 – 12/2026

South East Brabant Concession – Hermes part of Connexxion and Transdev NL

The Public Transport concession covers a region with 750.000 inhabitants

Main Cities:

Eindhoven: 225.000 inhabitants
Helmond: 90.000 inhabitants

The PT concession consists of:

City lines within Eindhoven and Helmond.
Interurban lines
Neighborhood buses (8 passengers) and school buses
Total concession contains today 215 buses

- ***Contract start :*** December 11, 2016
- ***Contract demands:*** Transition of the complete fleet to a Z.E. fleet before 1st of January 2025.

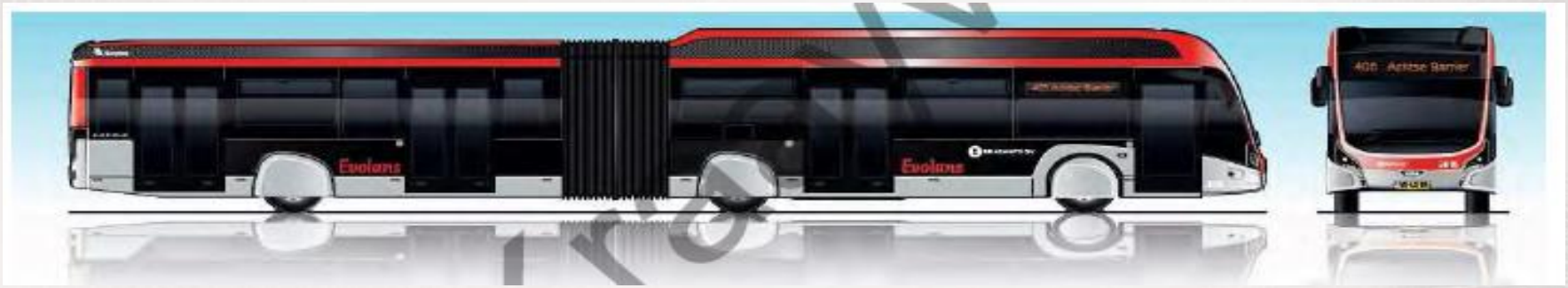
South East Brabant Concession – Hermes part of Connexxion and Transdev NL

Connexxion decided to offer an electric fleet in different phases and to operate a fleet of electric articulated buses from the start of the new concession.

models	Introduction of electric buses		
	Phase 1	Phase 2	Phase 3
	Dec. ’16 -	Jan ’19 - Dec’21	Jan ‘22 – Dec. ‘24
Articulated 18 m - 4 doors	43		
City 12 m - 3 doors		32	
Interurban 12 m - 2 doors		33	16
Urban 12 m - 2 doors			67
Mini bus			23
Taxi 8 passengers			5
Total	43	65	111

100% zero emission fleet: 219 vehicles at 01/01/2025

Electric articulated e-buses from VDL



- *Number of vehicles*: 43 articulated E-buses
- *Technology used:* Combination of overnight and opportunity charging

Bus specifications

- ***Battery capacity:*** 180 kWh (9 modules of 20 kW mounted on the roof).
- ***Range:*** Between 65 and 85 km (40 – 50 miles) with one charge.
- ***Passengers capacity:*** 47 fixed seats.
  89 standees.
  Total capacity: 136 passengers.
- ***Access to the bus:*** 4 double doors
  Manual ramp
- ***Comfort:*** Full air-conditioning system
  Heating with heat pump and additional diesel heat generator.
  Free WIFI and USB connection with every seat

Zuid - Oost Brabant e-Bus operational data

Bus line number	start	end	Number of bus stops	distance in km	average speed km/h	Needed batterie charge
400	bus station	airport	2	9,287	26,5	21
	airport	bus station		9,615	27,5	21
				18,902	**27,0**	**42**
401	bus station	airport	17	9,050	22,6	24
	airport	bus station		9,050	22,6	24
				18,100	**22,6**	**48**
402	bus station	veldhoven	20	11,482	23,0	30
	veldhoven	bus station		12,264	23,7	31
				23,746	**23,4**	**61**
403	bus station	oerle	20	10,887	24,2	27
	oerle	bus station		10,946	23,5	28
				21,833	**23,9**	**55**
404	bus station	summa	12	4,625	19,8	14
	summa	bus station		4,327	18,5	14
				8,952	**19,2**	**28**
405	bus station	rijssellaan	17	8,781	21,1	25
	rijssellaan	bus station		8,362	20,9	24
				17,143	**21,0**	**49**
406	bus station	Son Meubelplein	16	8,662	21,7	24
	Son Meubelpleir	bus station		8,287	21,6	23
				16,949	**21,7**	**47**
407	bus station	High Tech Campus	13	5,574	20,9	16
	High Tech Campu	bus station		8,475	21,2	24
				14,049	**21,1**	**40**

Charging equipment – Factor C

- **Charge and discharge rates** of a battery are **governed by C-rates.** The capacity of a battery is commonly rated at 1C
- ***C-rate of 1C is a one-hour charge*** (or discharge).
- Charging a 180 kWh battery pack with 1 C will take one hour.
- 0.5 C or C/2 this is a two-hour charge.
- High-performance batteries can be charged above 1C.
- Charging a 180 kWh battery pack with 1 C will takes one hour.
- Charging a 180 kWh battery pack with 1,5 C will take 40 minutes.

Charging equipment – Phase 1 conductive charging

- ***Charging strategy***:

- All battery charging is done at the depot in Eindhoven.
- The depot is located at 1,5 km from the railway station where all lines with electric buses starts and ends.
- Buses that will have to be charged will be replaced by a fully charged bus at the railway station.
- Slow charging during the night (4.5 hours)
- Fast charging during the day (40 minutes at charging speed 1.5 C).
- Therefore 6 extra buses for charging are needed

37 + 6 = 43 e-buses.

Charging equipment – Phase 1 conductive charging

- ***Charging equipment:***

- 10 MVA connection on e-network (only 50% used today).
- Installation of 3 transformers of each 1.600 KVA and to convert 10.000 Volt to 400 Volt.
- 10 DC fast chargers of 300 kW (2 hoods) - 3 fast chargers placed in open air, the others inside the depot.
- 22 DC slow chargers of 30 kW (1 hood) overnight charging.
- 2 mobile chargers (workshop),
- Monitoring charging equipment: *VDL bus manufacturer*

Amstelland - Meerlanden Concession

Connexxion, e-bus operation

Starting in December 2017 with 49 electric articulated buses on **R-net**
170 kWh battery pack
Additional 85 electric R-net buses end of 2020

Also starting in Dec. 17 with 51 electric articulated buses on **Schipholnet.**
Adding 2 e-buses during the contract.

Introducing **78 electric articulated high capacity e-buses** (>18 m) end of December 2020. Bringing the total electric fleet towards 266 units.

Hydrogen Bus project – The NL's

- Within the province of South-Holland, experience is gained in implementing and operating hydrogen fuel cell buses.
  - Number of buses: 4 (to be deployed on long distance route (>300 kilometer a day)
  - Start: Q3 2018
  - Duration: 3,5 year
  - Total distance: 1,2 million kilometer
  - Total costs: € 7,7 million (in addition to regular diesel buses)
  - Project is part of Fuel Cell Hydrogen Joint Undertaking (FCH-JU), project 3Emotion

  Local wind energy is used for hydrogen production