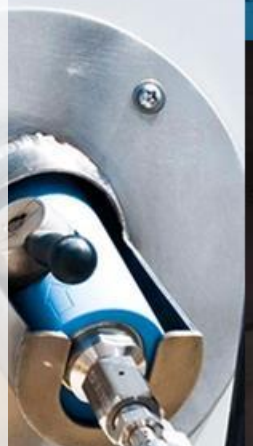
Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe

An initiative by the Fuel Cells and Hydrogen Joint Undertaking

Nicolas Brahy
Lyons, April 2015






Contents

1. Why should cities and regions look at fuel cell buses?
2. What has the FCH JU done so far?
3. Where we stand and the ongoing study
4. What the FCH JU would like to (co)finance?

Shifting public awareness towards sustainability and eco-friendliness requires new sustainable transport solutions

Europeans perceive major environmental problems…

> 50% of Europeans think that **climate change** is one of the three most important challenges our world faces

> 81% say that **air pollution** is an important problem

> 72% of citizens say that **noise pollution** is a problem in their cities

…to be caused by the transport sector…

> 63% feel that **transport is a main threat to air quality**

> 56% of Europeans think pollution can be reduced by improving **public transport**

> 71% of European citizens say that **electric cars are the most environmentally friendly mode of transport**

…and want local authorities to solve them

> 56% of Europeans think that public transport can best be improved by **city authorities**

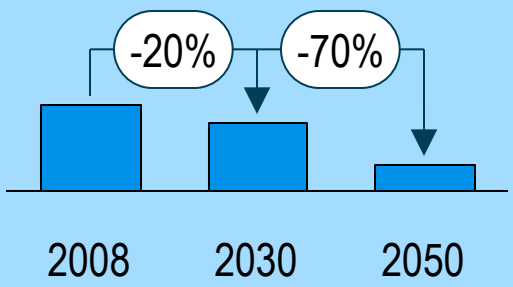
> 72% of Europe's population believe that public authorities **aren't doing enough to improve air quality**

Source: Eurobarometer "Climate Change" (2014); Eurobarometer "Urban Mobility" (2013); Eurobarometer "Air quality"(2013)

The EU and some countries as well as municipalities at the forefront have set ambitious targets – Stricter regulations expected

Emission reduction targets for transport in Europe (examples)

European Union



Netherlands

Make **entire bus fleet** in public transport **emission-free in 2025**

Hamburg

Purchase **alternative powertrains for buses** only **from 2020** onwards – Establish **emission-free bus fleet in 15-20 years**

Oslo/Akershus

Halve transport emissions by 2030 and develop hydrogen infrastructure to **increase the number of FC cars and buses**

> The EU aims at significantly reducing greenhouse gas emissions – Transport is an important lever

> The Clean Vehicles Directive and other emission regulations are already in place

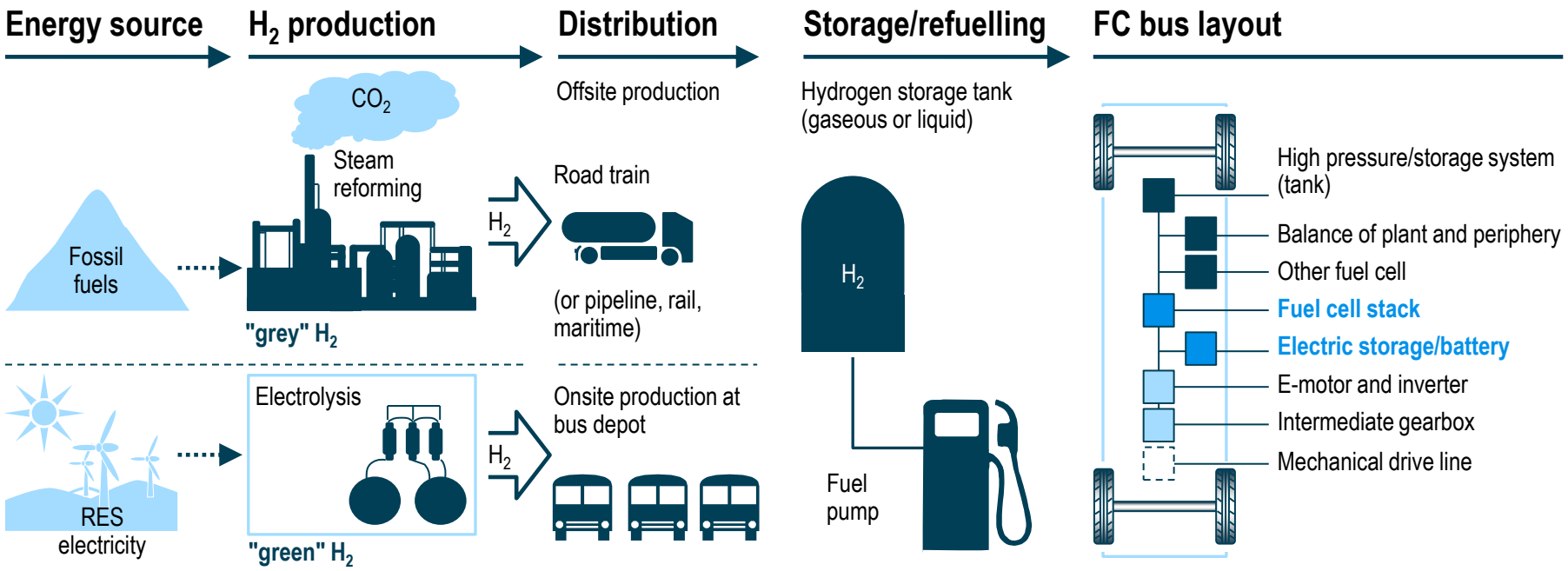
> Recently, the EU launched legal proceedings (incl. fines) against countries that have violated the **Directive on Ambient Air Quality**

> A number of pioneering European locations have set ambitious targets – Others are expected to follow suit

Source: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system

FC buses are powered by a fuel cell and an electric battery – They run on hydrogen and are zero emission

Hydrogen value chain and bus fuel cell system

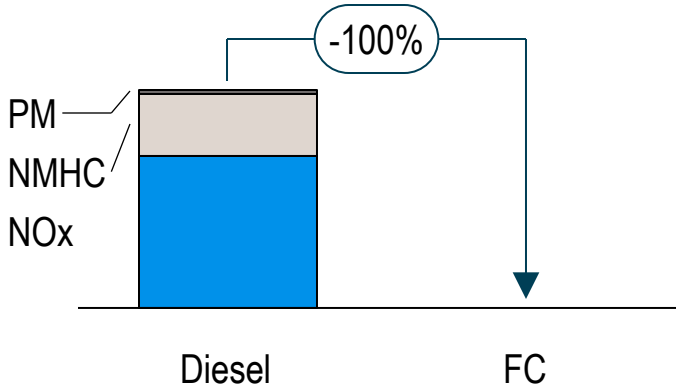


> Hydrogen is produced by steam reforming from natural gas or by electrolysis with electricity (e.g. from renewable energy sources)
> Hydrogen refuelling and storage infrastructure for bus fleets is mostly situated at the bus depots
> FC buses run on hydrogen and contain a fuel cell stack and battery at the heart of their powertrain
> The fuel cell stack converts hydrogen into electrical energy for propulsion – The battery stores excess and braking recuperation energy

Note: Biomethane can be used in SMR, which "cleans up" the hydrogen. Furthermore, technology to capture and store CO_2 (Carbon Capture and Storage – CCS) is in development – it comes with risks and costs, though

FC buses contribute to making cities cleaner and quieter, thereby increasing the quality of living

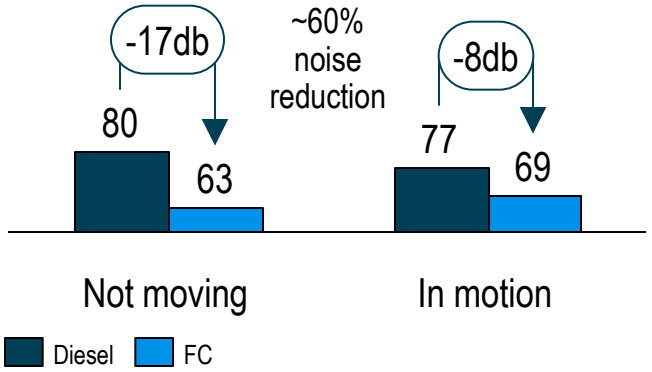
FC buses cause no local emissions[1)]



> Harmful local emissions of diesel buses can be completely avoided by FC bus deployment

> Lower local emissions improve citizens' health and reduce health costs

FC buses reduce noise levels



> FC buses reduce perceived noise levels by ~60% on average compared to diesel buses[2)]

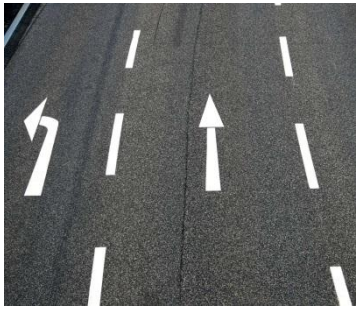
> Lower noise levels increase urban quality of life, mitigate external noise costs and increase property values

1) Local emissions for 1 litre of diesel fuel according to EURO VI norm
2) Non-linear db scale; -10db = 50% noise reduction; noise levels vary depending on terrain and driving style

FC buses are the most flexible zero emission option – Unlike other electric solutions, they can be operated like diesel buses

High daily ranges

… of 300 km on average without refuelling – Extension possible



Full route flexibility

… not bound to any required infrastructure on the route

Performance

… comparable to diesel buses, e.g. acceleration or gradeability

Fast refuelling

… down to 7 minutes possible – Also several refuelling cycles per day possible

High passenger comfort

… due to reduced noise levels and smooth driving experience

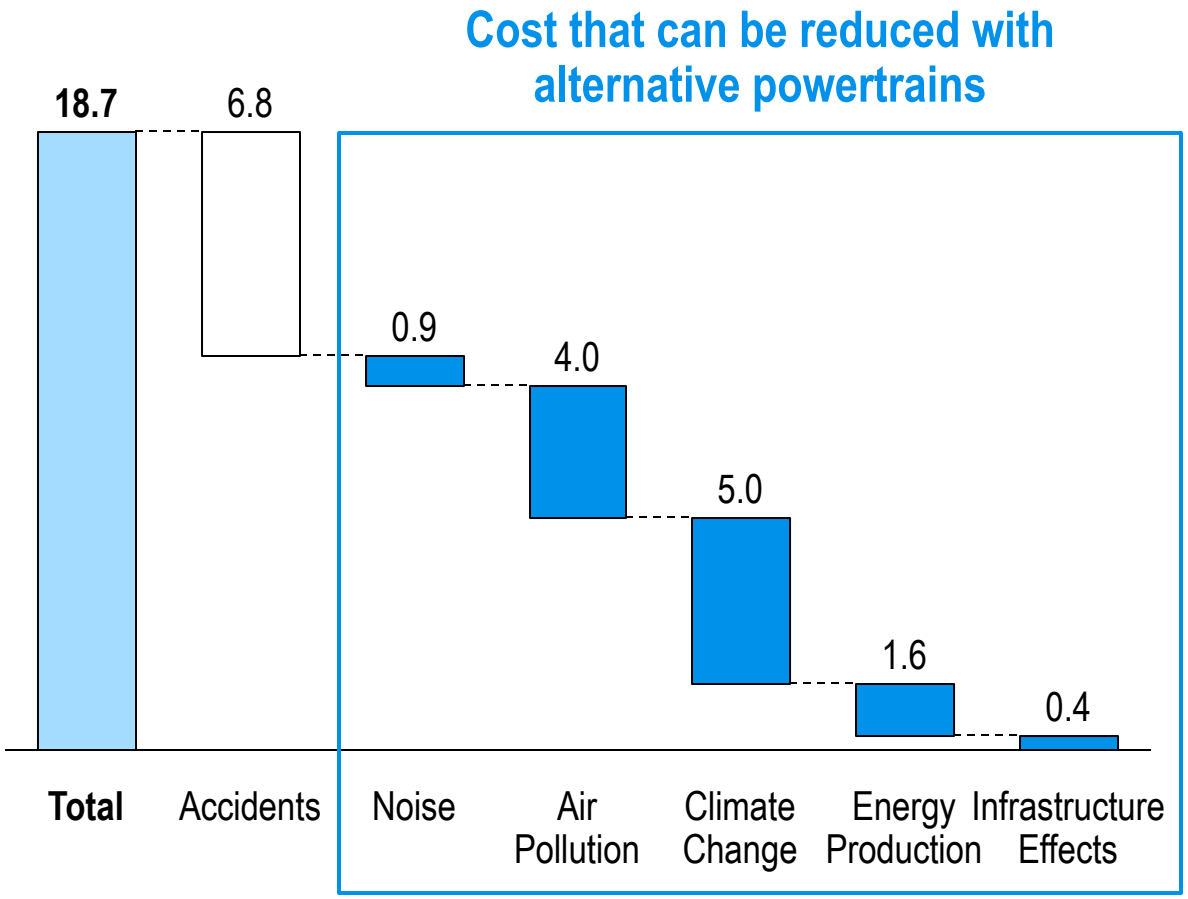
Close to technology maturity

… with more than ten years and 7M km of operational experience in Europe

Note: For a comparison of different alternative powertrain solutions please refer to the study "Urban buses: Alternative powertrains for Europe"

Deployment of FC buses alleviates external costs of buses, i.e. costs caused to third parties indirectly affected by traffic

Annual external costs of buses in the EU in 2008 [EUR bn]



> External health, environment and infrastructure costs for buses have been estimated at some EUR 19 bn annually in the EU – Other studies indicate even higher figures

> With FC bus deployment, cities can gain direct and indirect benefits by reducing external costs that outweigh extra technology costs

> The potential for reducing systemic costs is enormous and should be considered when assessing direct costs of FC bus deployment

Note: Study results vary significantly between the different studies available – There is a consensus, however, that significant cost reduction potential exists

Source: External Costs of Transport in Europe 2011, CE Delft

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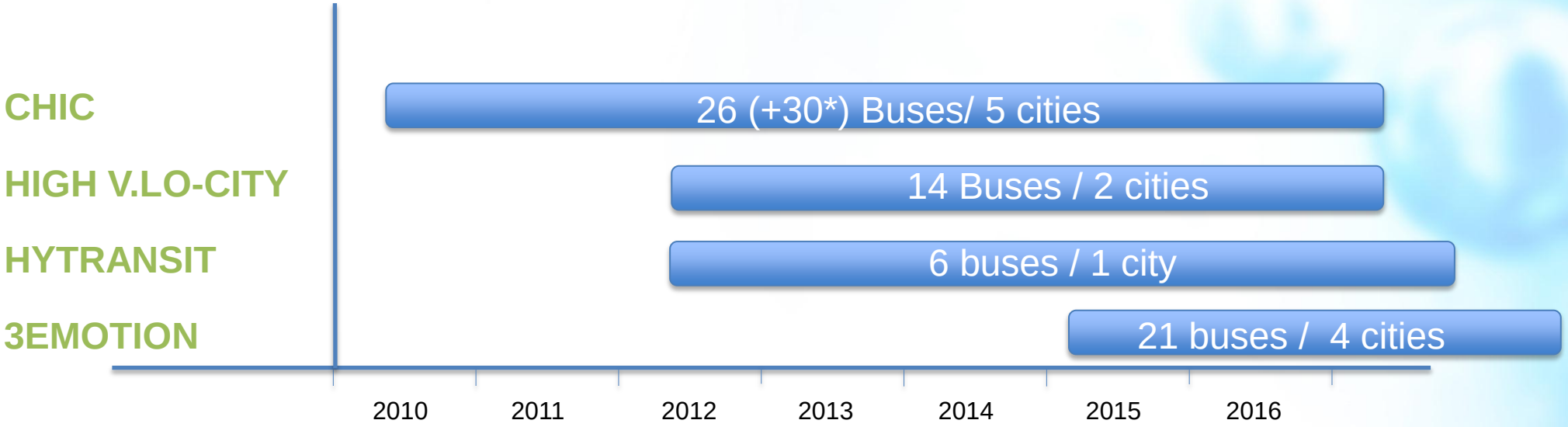
FCH JU (budget 2008-2013)
Bus Demo Projects



67 (83*) buses

15 cities/region

- London, Aarau, Oslo, Milan, Bozano, Cologne, Hamburg, Whistler
- Aberdeen, Flanders, San Remo
- Aberdeen
- Cherbourg , London, Flanders , Rotterdam, Rome

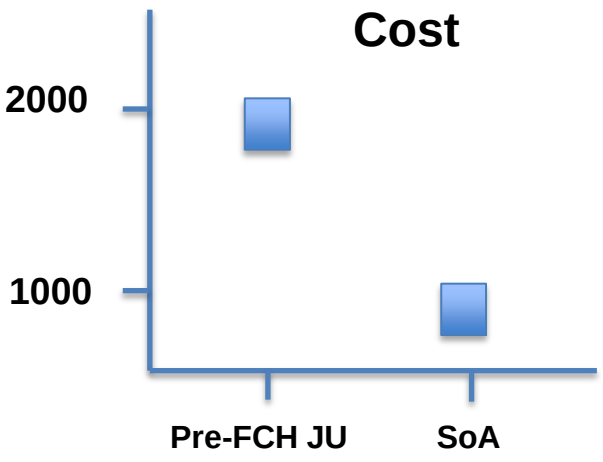
5 bus manufacturers

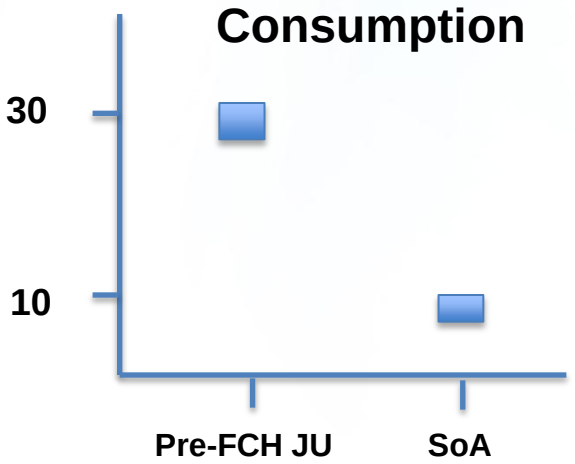
Mercedes
VanHool
VDL
Solaris*
Wrightbus

Total Budget: ~172 M
FCH JU Funding ~61.5 M

* Not funded by the FCH JU

Key learnings from “bus” projects





Refilling time ✓

- Availability: teething problems of new generation hybrid buses, now increasing to 80%, objective: >90%
- Price: declining but remains the main barrier
- Next step: test large fleets

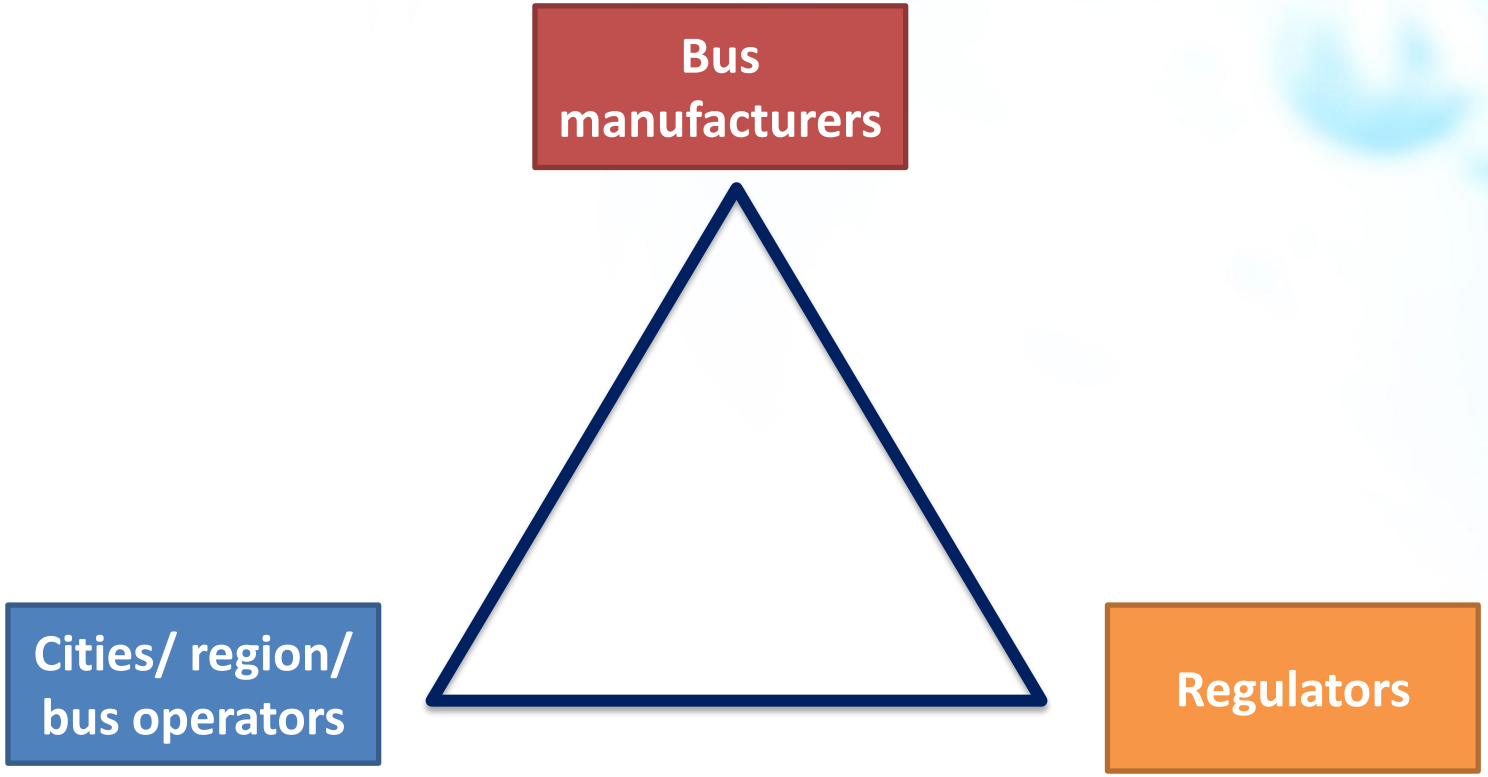
H2 Infrastructure:

- Availability and refilling time: 0K (97% and 7 min)
- Uncertainty about larger scale HRS
- Next step: engineering of large station -->starting

Contents

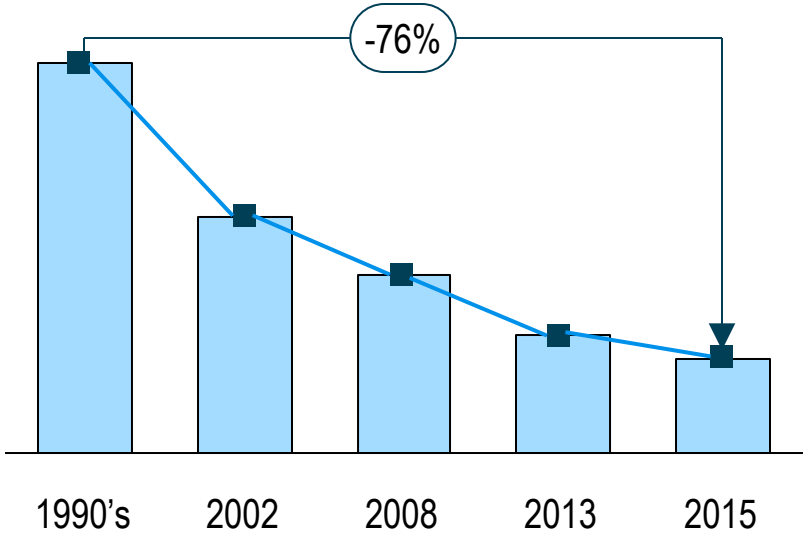
- General objective: commercialisation of FC bus
  - Conditions
    - Supply side: Bus manufacturers and H2 providers
      - Done: technology is available
      - To be done: move to industrial production: large volume and reasonable price
    - Demand side: cities and bus operators
      - Done: test the techno, show interest
      - To be done:
        - Bigger orders (from 5 to 20 or 100 buses)
        - More cities
    - Regulation:
      - Done: rationale for imposing clean public transport
      - To be done: confidence that compliance will be feasible and affordable
- Specfic objectives
  - Make the best use of the FCH budget 2014-2020: large scale demo projects
  - Partner with other funding sources

I am interested …
but please go first, I will follow



To unlock the situation we need to reach ~1000 FC buses

FC bus purchase price until 2015

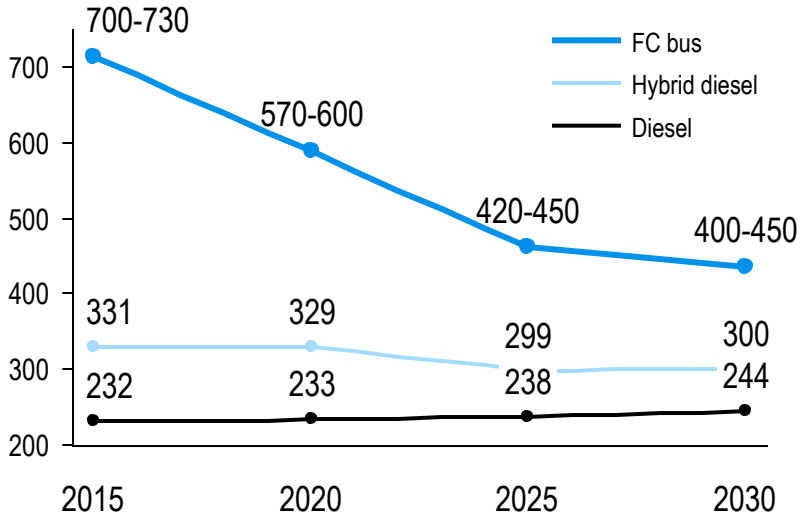


> So far, bus purchase prices have decreased by about 75%

> However, current price levels still remain a major challenge for commercialisation of the technology

Purchase price projection, solo FC bus

[EUR '000]

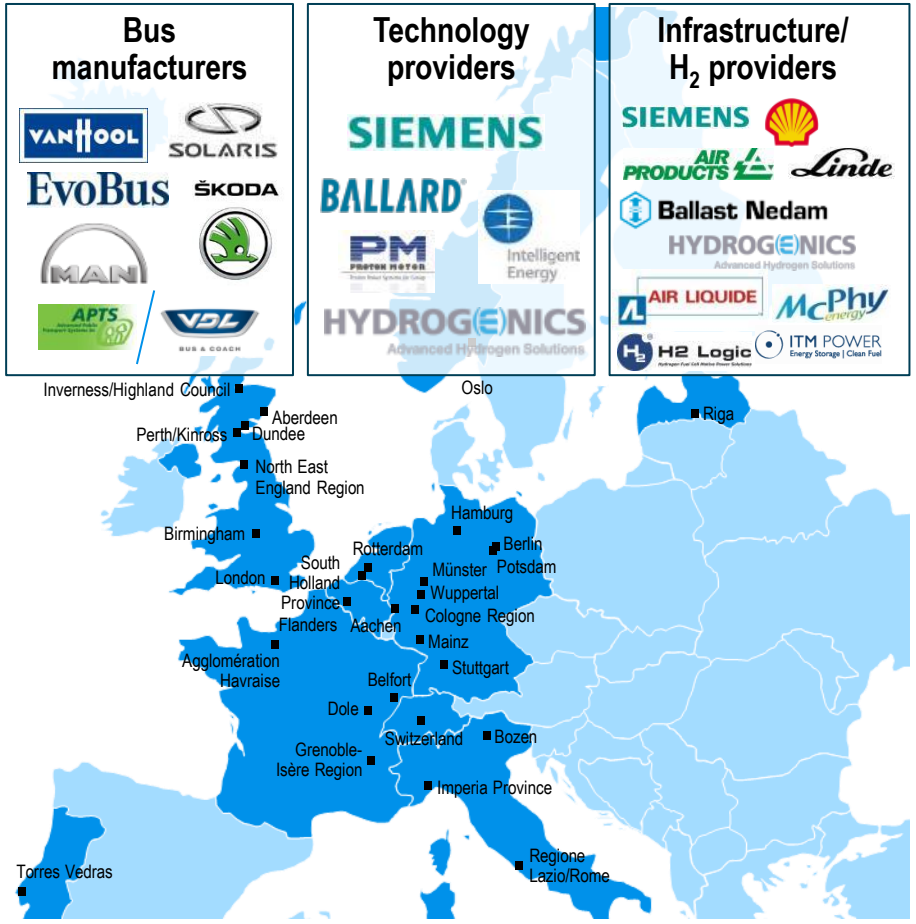


> Further price reductions are expected – depending on future sales volumes, prices could decrease to EUR 400,000-450,000

> Technological synergies with passenger cars carry further cost-down potential (not depicted here)

The coalition and FCH JU support operators in introducing FC buses

FC bus coalition & 35 participating locations



Benefits from participating

1. **Exchange experience and lessons learnt** with experienced coalition members
2. **Establish contacts in the industry** which can be useful for own concept developments
3. **Develop specific cost analysis** for your location
4. **Receive support in developing a communi-cation** strategy for your stakeholders
5. **Partner with other operators** to realise po-tential cost savings from **combined purchases**
6. **Gain the opportunity to receive funding / co-funding** from the FCH JU at a later stage of the project

At the FCH JU Forum in November, BUS manufacturers have indicated commitment and what is needed next

LoU Handover-Ceremony in Brussels, 12th November 2014

Left to right: First Mayor Olaf Scholz (Hamburg), Deputy Mayor Kit Malthouse (London), Filip van Hool (CEO Van Hool), Dariusz Michalak (Deputy CEO Solaris), Rémi Henkemans (Managing Director VDL Bus & Coach), Gustav Tuschen (Head of Product Engineering Daimler Buses)

- **Olaf Scholz, First Mayor of Hamburg, clearly indicated commitment** to large scale roll-out of FC buses in Hamburg – This was underlined in an interview published in the Handelsblatt, a major German daily newspaper with business focus
- **Kit Malthouse, Deputy Mayor of London, underlined the importance of FC buses** and called upon the industry to take the next step, indicating that the "bride" (policy and operators) was ready and awaiting a marriage proposal from the groom (industry), i.e. clearer industry commitment and lower prices
- **Prof. Mohrdieck, Director Drive Development Fuel Cell System Daimler presented cost projections** indicating that the FC bus purchasing price can be on the level of the price of a hybrid diesel in the long run
- **All OEMs underlined commitment** to invest in the technology as stated in the LoU

Contents

Organising a joint effort

- Regions, cities and bus operators
  - Joint procurement and/or large orders able to push price down
  - Co-financing
- Bus OEMs (including their supply chain)
  - Reasonable and declining prices
- H2 and infrastructure providers
  - Reasonable and declining prices
- FCH JU
  - substantial co-financing

Illustration: potential scenario

FOOD FOR THOUGHT

Joint Procurement 1
110 bus & 5 Station

- City A: 20 bus + 1 Station
- City B: 20 bus + 1 Station
- City C: 20 bus + 1 Station
- City D: 20 bus + 1 Station
- City E: 30 bus + 1 Station

Procurement 3

- City H: 40 bus + 1 Station

300 buses
+
11 Station

Joint Procurement 2
60 bus + 1Station

- City F: 30 bus + 1 Station
- City G: 30 bus (Station existing)

Joint Procurement 4
90 bus + 4 Station

- City I: 20 bus + 1 Station
- City J: 20 bus + 1 Station
- City K: 30 bus + 1 Station
- City L: 20 bus + 1 Station

These orders can be organised into 2 or 3 projects

A European initiative with national/regional cluster s

So far, 4 regional clusters have been formed – Scotland and UK should merge

	Cluster set up	Group defined	Deployment plan defined	Discussion Joint procurement started	Approach defined
Netherlands	✓	✓		✓	
Germany	✓	✓	✓		
Scotland	✓	✓			
UK (England)	Ongoing				
France	✓	✓			

A Letter of Understanding of Regions, cities and bus operators

LETTER OF UNDERSTANDING

Contents and commitment

> Greening public transportation is necessary
> FC buses are the most flexible zero emissions alternative
> Deliberate rolling out FC buses by the year 2020
> In the long run, replacing a certain part of the bus fleet with FC buses
> Deliberate engaging in joint procurement
> Financing parts of the funding gap
> Outlining required prerequisites for large-scale roll-out of FC bus technology

Next steps

> Agree on final version of the text
> Operators and local governments to initiate signing process
> Signing until end May 2015

- Interested
  - In joining the Fuel Cell bus coalition
  - in joining a national cluster (UK, Netherlands, France, Germany, etc.)
  - In co-financing FC buses

- Contact
  - Carlos Navas carlos.navas@fch.europa.eu +32 2 221 81 37
  - Enrique Giron enrique.giron@fch.europa.eu 32 2 221 81 36
  - Nicolas Brahy Nicolas.brahy@fch.europa.eu 32 2 221 81 32

- BACK-UP SLIDES

Investing in FC buses bears significant benefits for five reasons

Politically

There is a push for reducing emissions in public transport

Environmentally

FC buses help to reduce noise levels, to green cities and public transport

Operationally

FC buses are the most flexible zero emission option

Economically

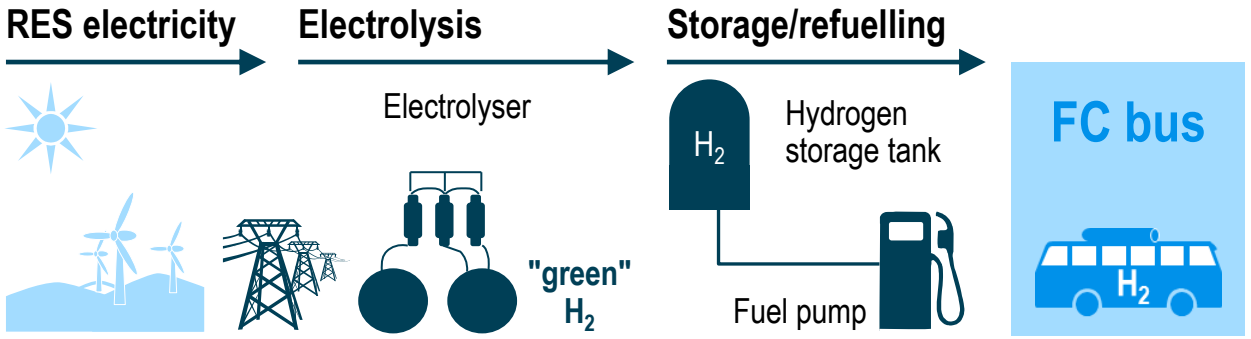
FC buses reduce external costs of public transport

Organisationally

The coalition and the FCH JU support operators in introducing FC buses

With electrolysis, the potential environmental benefits of FC buses extend well beyond zero local emissions

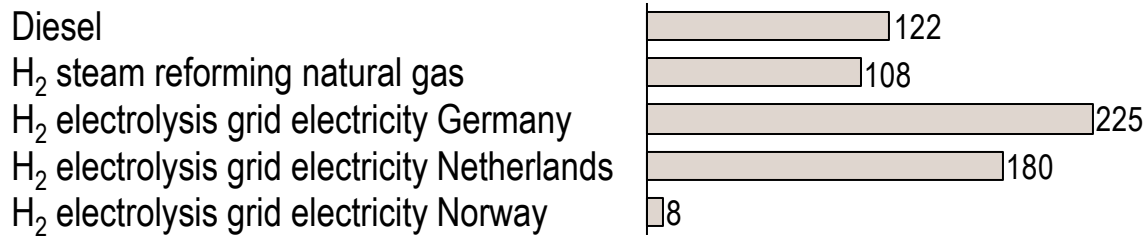
Hydrogen as a fuel can be completely "green"



- Zero emissions along the entire value chain can be achieved with hydrogen produced from 100% renewable energy sources (RES)
- In this case, one FC bus saves approx. 800 tons of CO_2 in its lifetime (amount of diesel bus emissions)

CO_2 footprint of electricity is crucial

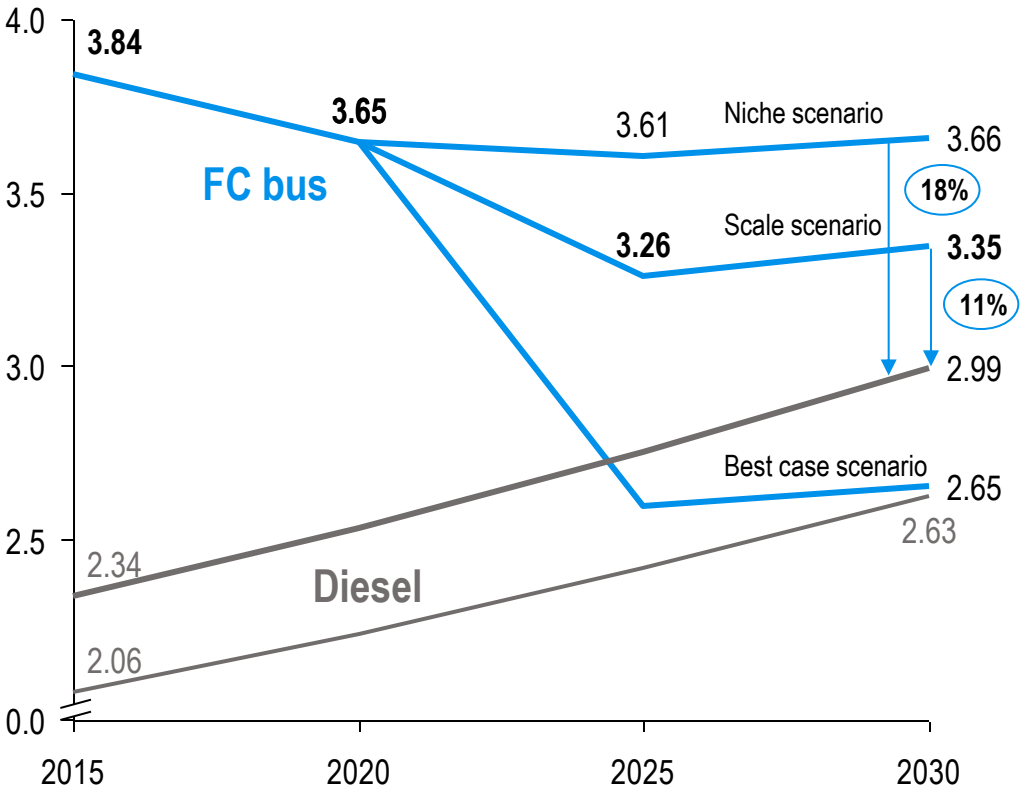
CO_2 emissions of bus fuel (well-to-wheel) in 2015 [kg/100 km]



- The carbon footprint of hydrogen produced by electrolysis with grid electricity depends on the local energy mix
- For saving or completely reducing overall emissions, a high share of RES in electricity is needed in the energy mix

Costs of FC buses are expected to decrease with a remaining cost premium of 11-18% compared to conventional diesel buses in 2030

Total Servicing Cost development scenarios, solo bus [EUR/km]



1,500 FC buses until 2025

8,000-10,000 FC buses until 2025

Best case scenario: Lower hydrogen and financing costs and increased FC bus lifetime assumed

> Total cost gap to the diesel bus expected to decrease to 11% in 2030, may remain higher though

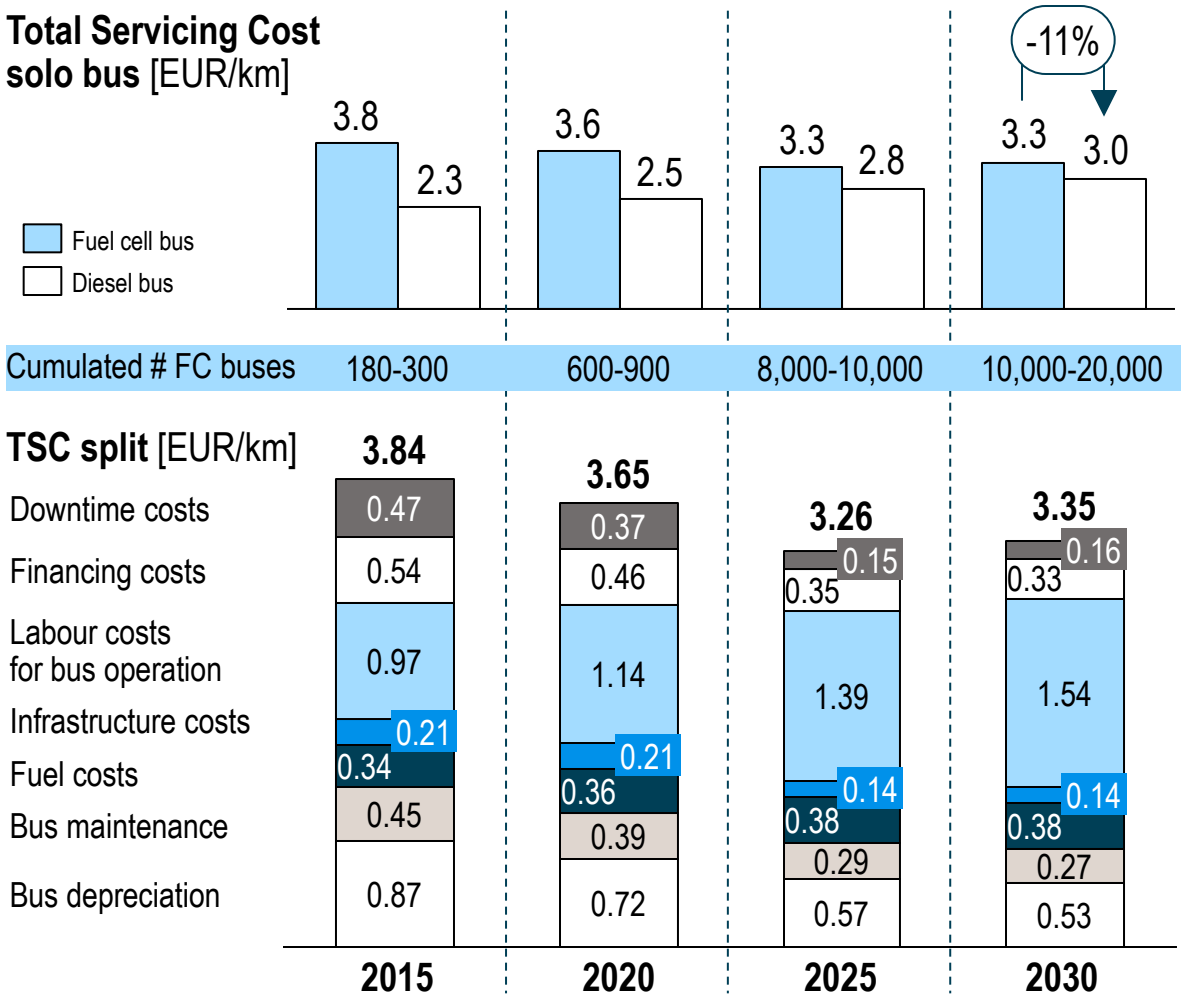
> Deploying more buses earlier will support scale effects and cost reduction

> More locations need to be mobilised as first movers

> Synergies with fuel cell passenger car industry offer further significant cost reduction potential (not depicted here)

TSC = Total Servicing Cost: TCO plus diesel bus replacement cost due to lower availability of FC buses

The cost development highly depends on the total number of FC buses deployed in the years ahead



> In 2030, a cost premium of 11% is expected for the FC bus

> By 2025, ~8,000 FC buses need to be deployed for the cost projections to materialise

> The largest cost components are labour, bus purchasing and financing costs

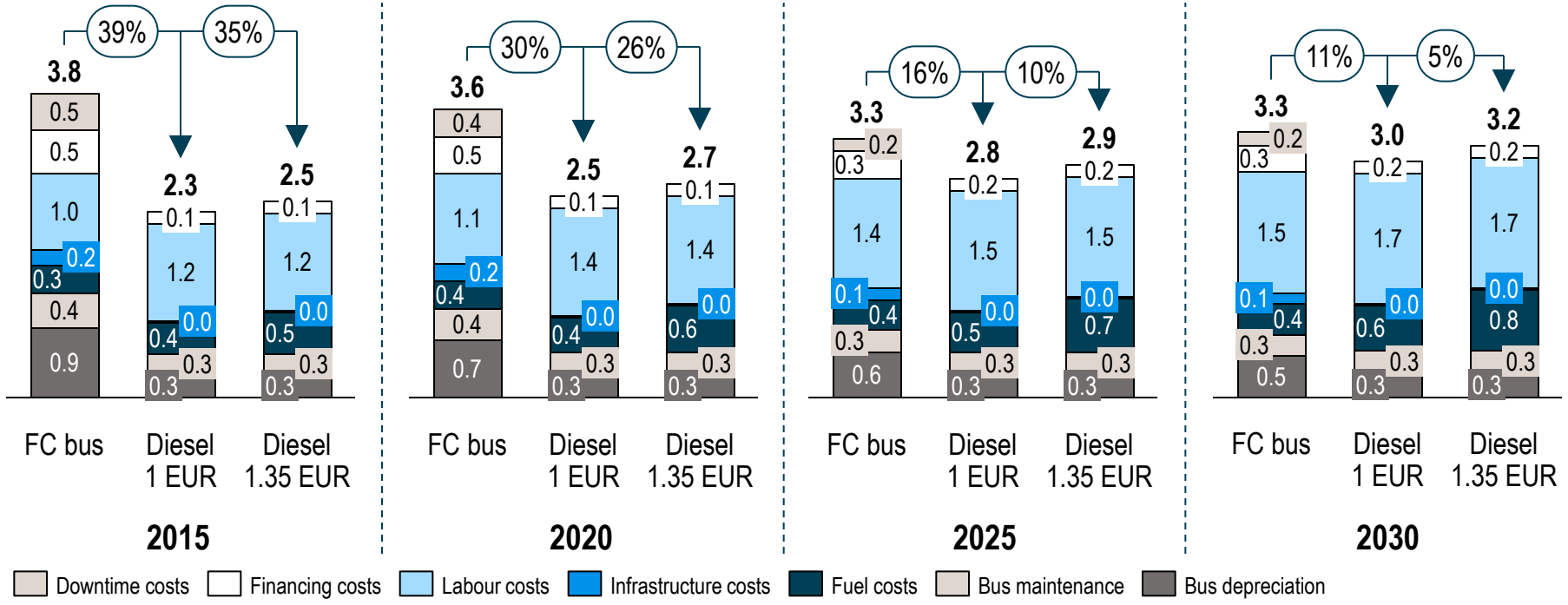
> Reducing the purchase price of the bus and of hydrogen infrastructure are important levers for reducing total costs

> Labour costs do not drive cost gap to diesel bus, as these are expected to be roughly equal

TSC = Total Servicing Cost: TCO plus diesel bus replacement cost due to lower expected availability of FC buses

Creating a level playing field with diesel fuel can aid commercialisation of FC buses

TSC comparison of standard FC and diesel buses [EUR/km]

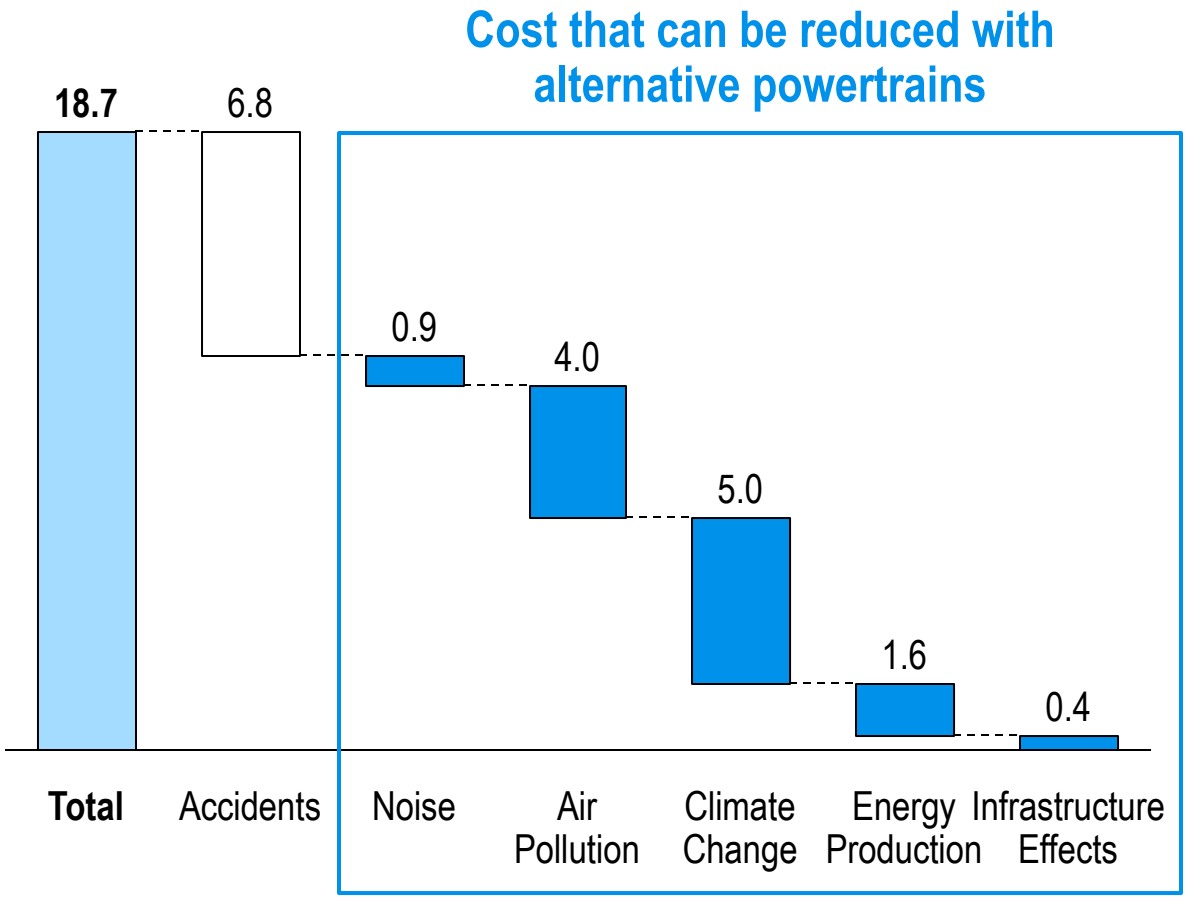


> The main cost difference is the higher FC bus purchase price, infrastructure costs and associated financing costs
> Maintenance costs are expected to even out after 2020, fuel costs will become higher for diesel
> If operators were to pay average consumer diesel prices, total costs could be on a par in 2030
> This underlines the fact that the regulatory and support framework greatly influences commercialisation

TSC = Total Servicing Cost: TCO plus diesel bus replacement cost due to lower expected availability of FC buses

Deployment of FC buses alleviates external costs of buses, i.e. costs caused to third parties indirectly affected by traffic

Annual external costs of buses in the EU in 2008 [EUR bn]



> External health, environment and infrastructure costs for buses have been estimated at some EUR 19 bn annually in the EU – Other studies indicate even higher figures

> With FC bus deployment, cities can gain direct and indirect benefits by reducing external costs that outweigh extra technology costs

> The potential for reducing systemic costs is enormous and should be considered when assessing direct costs of FC bus deployment

Note: Study results vary significantly between the different studies available – There is a consensus, however, that significant cost reduction potential exists

Source: External Costs of Transport in Europe 2011, CE Delft

FCH JU projects: CHIC

Aargau

5 EvoBus buses

Bolzano

5 EvoBus buses

London

8 Wrightbus buses

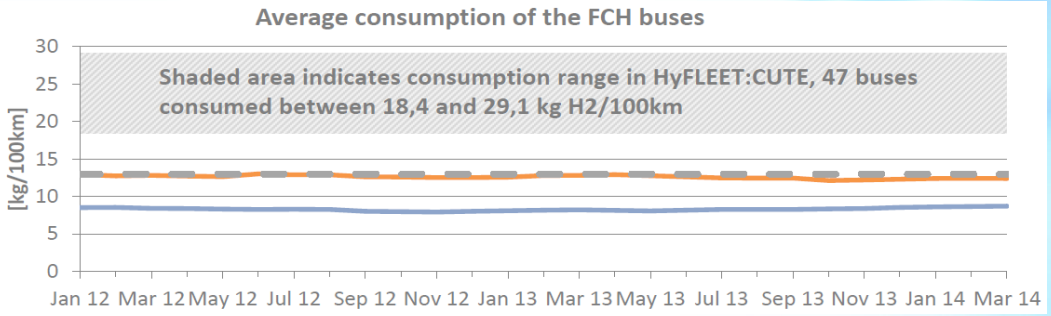
Milano

3 EvoBus buses

Oslo

5 Van Hool buses

CHIC



- Operation of **26 fuel cell buses** in 5 cities in Europe (**Aargau, Bolzano, London, Milano, Oslo**) and the respective infrastructure for a period of 5 years
- Transfer of learning from cities with experience in operating buses and infrastructure (Hamburg, Berlin, Cologne, Whistler; ~ 30 fuel cell buses) to the 5 cities
- Assessment of the technology with focus on environment, economy and society
- Dissemination to the general public and to cities preparing for the technology in the next step
- Demonstration phase 2010-2016
- **Cost 82 M€, 26 M€ funding**

City	HRS Availability to date (as of Sept 2013)	Average Refilling time
London	>98%	9 min
Aarau	>98%	6 min
Oslo	>98%	7 min
Cologne	>98%	7 min
Hamburg	83% (Mar-Sept ’13: 96%)	7 min
Whistler	>98%	20 min

FCH JU projects: High V.LO City

Aberdeen (UK)

Antwerp (Belgium)

San Remo (Italy)

- Implement 14 hybrid fuel cell buses in 3 regions
- Establish 3 hydrogen production and refuelling facilities
- Create a Network of Clean Hydrogen Bus Centres of Excellence (CHBCE)
- Evaluate the total cost of ownership of buses
- Contribute to the Standardisation of Hydrogen refuelling Infrastructure
- Facilitate policies on environmental, health, energy efficiency, social and economic benefits
- Increase awareness, promotion and broader adoption of hydrogen buses
- Budget: 31.6 M€, funding 13.5 M€

Sites	Flanders	Liguria	Scotland
Buses	5	5	4
FC Module Warranty	>12,000 operating hours = 1,000 hours		
Bus Availability	90% (excl. P.M.)		
H_2Consumption	9-10kg/100km		

FCH JU projects: HyTransit

HyTransit

- Part of the Aberdeen Hydrogen Bus Project – together with High V.LO-City
- Operation of 6 FCBs (+4 from High V.LO-City)
- Use of hydrogen storage as a means of managing electrical grid constraints
- Budget: 16.3 M€, funding 7M€

Aberdeen HydrogenBusProject

Fuel cell bus in Aberdeen (UK)

FCH JU projects: 3EMOTION

3EMOTION
environmentally friendly, efficient, electric motion

- Operate 21 new fuel cell buses in 5 regions:
  - Cherbourg (France)
  - London
  - Flanders (Belgium)
  - Rotterdam (Netherlands)
  - Rome

- Extend operation of 6 FCBs in London
- Develop 3 new Hydrogen Refuelling Stations
- Using latest technology, objectives are to achieve
  - 90% availability
  - Lower H2 consumption (<9kg/100km)

- Budget: 41.9 M€, funding 15M€

Achievements
Buses