Comparing e-buses

Hamburg, 17th/18th November 2014

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Framework Conditions

- Policy: from 2020 only low emission buses to be purchased
- Implementation of EU clean air regulations (and noise to come)
- Transition towards renewable energy/wind in national law and regional objectives
- Annual increase of passengers 2%, with growing rate of „environmentally orientated customers“ (not necessarily captive riders)
- Consideration of socio-economic developments in mobility
- Future availability and cost of fossil fuels?

Why Electric Buses?

- Use of buses up to 12/14 years: long term strategy for safe energy supply needed
- Introduction of new technology (workshops, refuelling) only doable step by step
- Sufficient time for education and on-the-job training
- Functional view: different powertrains for different types of operation
- CAPEX and OPEX but also productivity and flexibility to be considered
- High launching costs more economic than a later immediate implementation in larger quantities at one time

Quelle FFG

Innovative Buses in Hamburg

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Fuel cell buses

- Since 1999: Development and tests of hydrogen powered fuel cell buses with the industry
- Since 2003: HyFLEET:CUTE with up to 9 fuel cell buses
- Since 2011: New generation of fuel cell hybrid buses, consumption: 8 kg hydrogen/100 km; range: 350 km
- Next generation fuel cell buses expected in 2017/18

Hybrid buses

- Since 2010: Diesel-electrical serial hybrid buses (EvoBus)
- Since 2010: Operation of parallel hybrid buses (VOLVO) at HOCHBAHN subsidiaries (2014: > 60 buses)
- Ongoing tests with hybrid buses of other companies

Plug-In Hybrid and battery buses

- Tests with plug-in buses starting in winter 2014/15
- Battery buses in 2016

Bus Operation

„Innovation line“ 109

- Distance: 10 km (central station - U Alsterdorf - central station)
- Concept: exclusive use of innovative buses
- Operation of PHEV as well as BEV and FCHB
- BEV: electrically all distance
- Bus stops provide suitable information systems

Criteria for the selection of Innovation Line

- Length of line (number of charging stations)
- Availability of space and energy supply during charging
- Public perception (inner city traffic)

Fuel Cell Citaro

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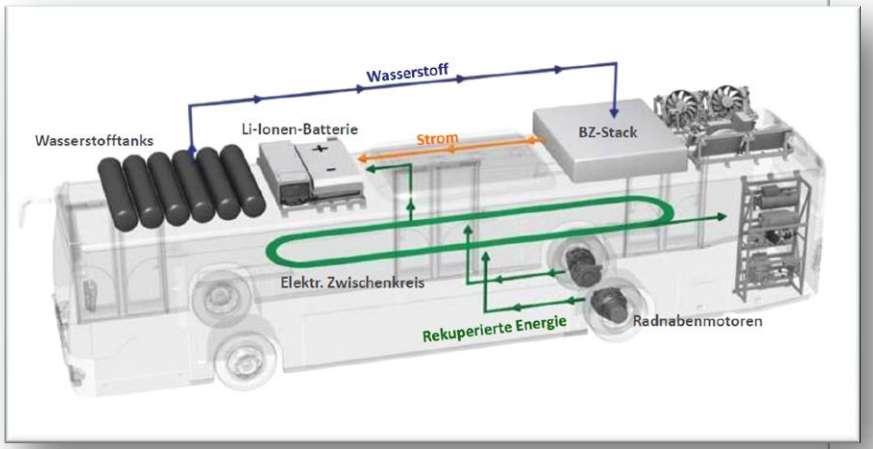
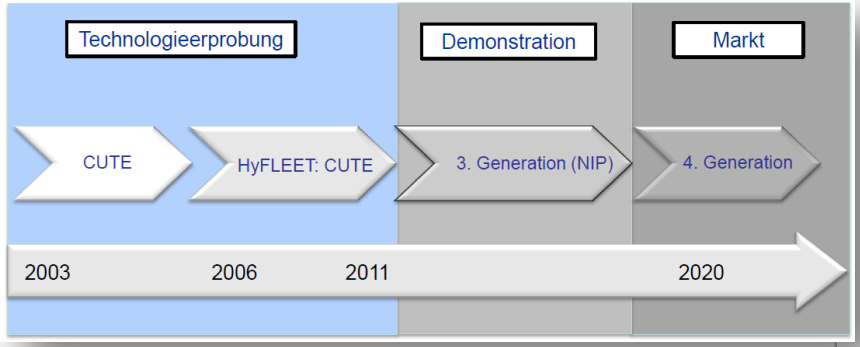
- Currently 4 buses in operation
- Guarantee fuel cells: 15,000 h or 5 years
- Serial hybrid, recuperation
- Consumption: 8kg/hydrogen per 100 km; more than 50% reduction compared to last bus generation
- All auxiliaries electric
- Availability currently still at 60 - 80%, target next phase 85 %
- High driving comfort
- High acceptance by passengers and drivers





Solaris Urbino Fuel Cell

Fuel cell hybrid articulated bus (18,75 m)

- supply of 2 buses by end of 2014

Quelle: SOLARIS

Vehicle concept

- Fuel cell hybrid bus with plug-in function and fuel cell as range-extender
  - Fuel cells: Ballard FCvelocity HD7, 101 kW
  - Lithium iron phosphate battery: 120 kWh (Base: A123)
  - Energy management: Vossloh Kiepe

Targets and agreements

- Availability: 70% in the first year, 80% from the second year
- Expected consumption: 13 kg H2 / 100 km
- Guarantee: 5 years, 15,000 hours for the fuel cells
- Technical support largely by HOCHBAHN/FFG, successive transition with „Flying Doctors“
- Common technical optimization and further development of vehicles

Hydrogen buses: current status

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Germany
- Hamburg 4 (+2), Karlsruhe 2, Stuttgart 4, Cologne 4

European joint project HighVLOCity
- 5 European partners (Flanders, Liguria, Aberdeen)
- 14 Buses and 3 refueling stations/production units 2012 until 2016

European joint project CHIC
- 12 European partners (Bozen, London, Milano, Switzerland, Oslo)
- 52 Buses and one refueling station for each location 2010 until 2016

European joint project HyTransit
- 5 intercity buses
- Extension of Aberdeen project with 1 refueling station 2012 until 2017

European joint project 3 E-Motion
- 21 Buses Van Hool

USA, Canada, Brasil
- Approx. 35 fuel cell buses operated
- More projects in preparation

nip

HIGHVLOCITY

HyTransit

California

Technical optimizations until 2020

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- Operation of buses/fuel cells up to 40,000 hours: Technical advancement and optionally exchange methods (incl. recycling)
- Modular operation of essential vehicle components (economies of scale)
- Conceptual development (e.g. downsizing of expensive components)
- Supply of all components within 24 h
- Standardization of tests, complete diagnostic tools and routines

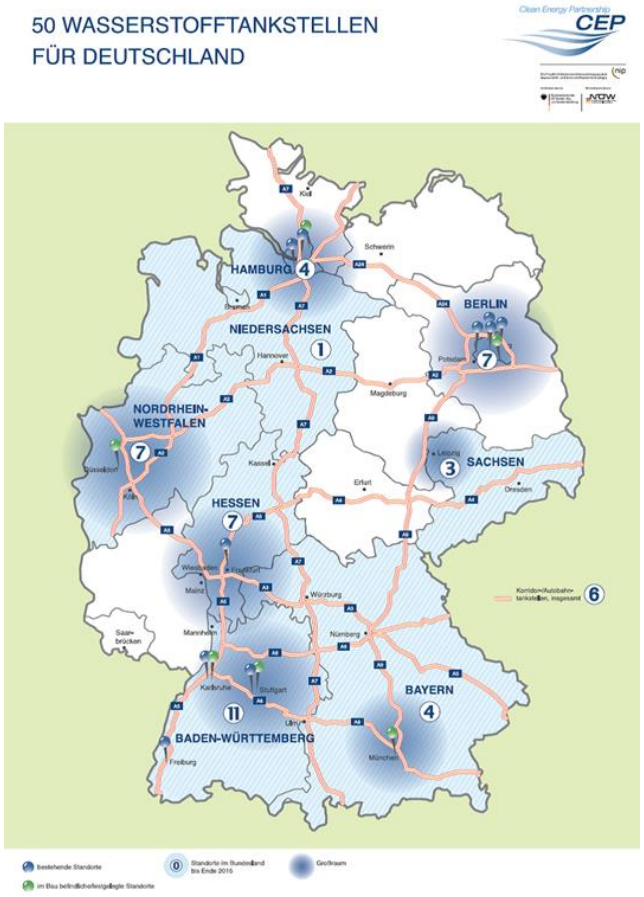
Hybrid FC Buses (12m, low floor)	Current Values	Next Generation	Diesel Bus (12m, low floor)
Fuel Economy	**8 - 15 kg/100 km** (up to 30% improvement over an *equivalent* diesel route at parity of caloric content)	**7 - 12 kg/100 km** (from 20 - 40% improvement over an *equivalent* diesel route at parity of caloric content)	**35- 50 litre/100 km** (approx. 11- 15 kg/H2/100 km at parity of caloric content)
Range	250 - 350 km	up to 450 km	>> 400 km
Availability	55 -80%	> 90 %	> 90%
Refueling Time	7 - 10 min/bus	< 7 min/bus (depending on tank size)	<< 5 min/bus

Quelle: Next HyLights 2011

Refueling infrastructure

Hamburg

- 5 public refueling stations (3 already in operation)
- Master plan for Germany: connection with Berlin and Scandinavia
- Additional 3 refueling stations (airport, Zemship, depot Hummelsbüttel)

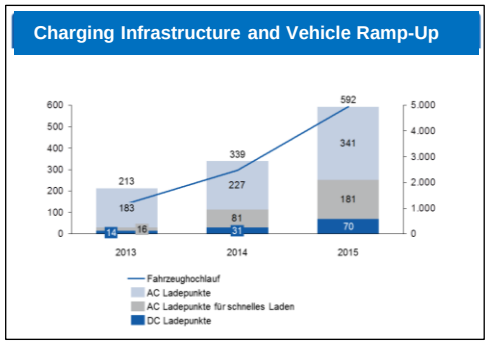


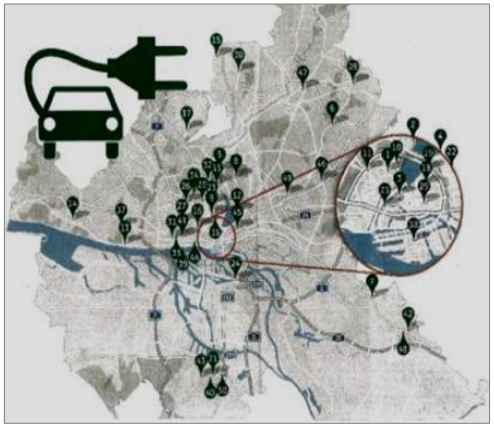
Quelle: CEP

Supply Requirements

- Sufficiently large hydrogen refueling stations with reliable availability
- Refueling (35 kg hydrogen) in 5 - 7 min
- Reasonable price for hydrogen (< 6 Euro)
- Strategy for supply (make or buy) at the depots
- Plans for logistics and storage of large volumes of hydrogen (at depots etc.) and their implementation

BEVs successfully implemented





Achievements

- 1.000 BEV in operation
- With approx. 260 vehicles largest battery-electric fleet in public services in Germany
- More than 250 charging spots form a very dense network of recharging stations – thereof 50% in public space
- 100% green electricity in all cars
- Initiator on national level for best-practice and legislation

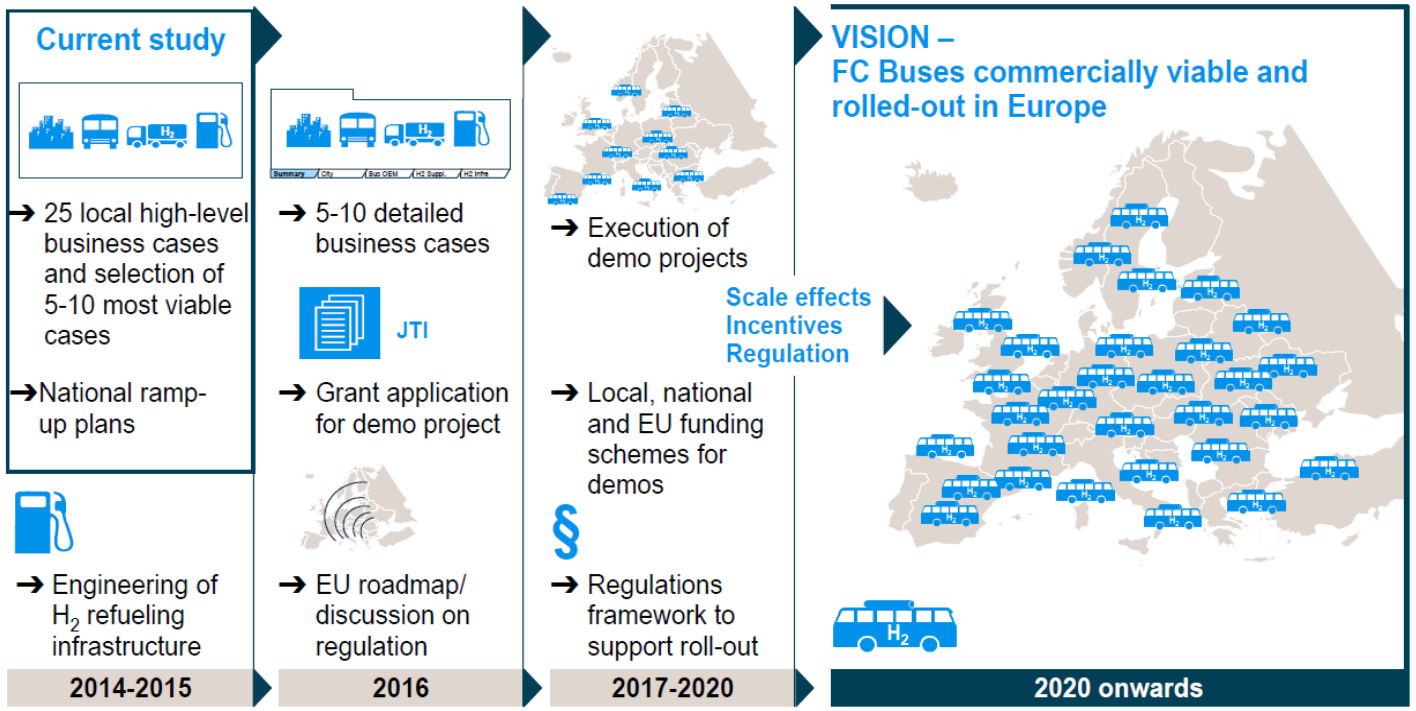
Future plans

- 20,000 vehicles by 2020
- ″Electric neighbourhoods“ - urban or residential areas with low-emission vehicles
- Masterplan public charging points:
  - 592 charging points plus 70 fast charging points
- Smart charging for faster and more convenient use
- Smart grids to improve integration of renewable energies into the grid

Source. Abendblatt

EU Commercialisation Study (I)

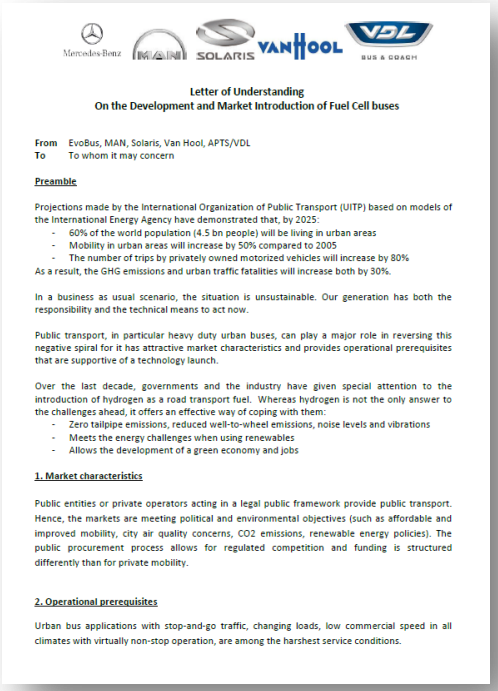
The FCH JU and coalition follow a bold vision of commercialising FC buses in Europe through demo projects and ramp up scenarios



EU Commercialisation Study (II)

EU Commercialisation Study (III)

Joint Letter of Understanding from bus OEMs to Mayors of Hamburg and London representing 30 European regions



Mercedes-Benz MAN SOLARIS VANHOOL VDL BUS & COACH

Letter of Understanding
On the Development and Market Introduction of Fuel Cell buses

From EvoBus, MAN, Solaris, Van Hool, APTS/VDL
To To whom it may concern

Preamble

Projections made by the International Organization of Public Transport (UITP) based on models of the International Energy Agency have demonstrated that, by 2025:

- 60% of the world population (4.5 bn people) will be living in urban areas
- Mobility in urban areas will increase by 50% compared to 2005
- The number of trips by privately owned motorized vehicles will increase by 80%

As a result, the GHG emissions and urban traffic fatalities will increase both by 30%.

In a business as usual scenario, the situation is unsustainable. Our generation has both the responsibility and the technical means to act now.

Public transport, in particular heavy duty urban buses, can play a major role in reversing this negative spiral for it has attractive market characteristics and provides operational prerequisites that are supportive of a technology launch.

Over the last decade, governments and the industry have given special attention to the introduction of hydrogen as a road transport fuel. Whereas hydrogen is not the only answer to the challenges ahead, it offers an effective way of coping with them:

- Zero tailpipe emissions, reduced well-to-wheel emissions, noise levels and vibrations
- Meets the energy challenges when using renewables
- Allows the development of a green economy and jobs

1. Market characteristics

Public entities or private operators acting in a legal public framework provide public transport. Hence, the markets are meeting political and environmental objectives (such as affordable and improved mobility, city air quality concerns, CO_2 emissions, renewable energy policies). The public procurement process allows for regulated competition and funding is structured differently than for private mobility.

2. Operational prerequisites

Urban bus applications with stop-and-go traffic, changing loads, low commercial speed in all climates with virtually non-stop operation, are among the harshest service conditions.

Thank you very much for your interest!

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