Experiences from using hydrogen in public transport

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Henning Niemeyer
MVV Consulting GmbH

On behalf of
Berliner Verkehrsbetriebe (BVG)

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Structural data of Berliner Verkehrsbetriebe (BVG)

BVG

11,819 Staff
405 Trainees / Apprentices
12,224 Total

Underground

- 144.9/120.3 km total route length (day/night)
- 9 day-time lines
- 7 night lines
- 6 workshops
- 170/145 stations (day/night)
- 1,372 vehicles
- 2,791 staff
- 456.8 passenger trips / year

Tram

- 285.5/59.7 km total route length (day/night)
- 21 day-time lines
- 5 night lines
- 6 depots
- 374/115 stops (day/night)
- 602 vehicles
- 1,634 staff
- 171.3 million passenger trips / year

Bus

- 1,626/751 km total route length (day/night)
- 150 day-time lines
- 54 night lines
- 2,601/1,504 stops (day/night)
- 1,388 buses
- 6 depots
- 3,931 staff
- 407.1 million passenger trips / year

Environmental measures so far tested in BVG's buses

Technology	*Vehicle*	*Additional costs compared to diesel*
Methanol (1985 - 1988)	7 MAN SL 200 7 Mercedes Benz O305	approx. 28%
CNG (1996 - 1999)	4 MAN NG 232 2 Mercedes Benz O405 GN 4 Mercedes Benz O405 N	approx. 20%
Aquazole* (1999)	15 buses	approx. 8% / 100km additional consumption
CRT (1999 - 2001)	800 buses retrofitted	approx. 5500 EUR/unit
Euro 5 / EEV (2003 – to date)	25 VOLVO buses	Funded by German Environ. Ministry

And last but not least: **hydrogen ...**

* Diesel water blend helping to reduce NOx emissions

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Berlins first hydrogen filling station: The Hydrogen Competence Centre (I)

Inauguration:	23 October 2003
Location:	Usedomer Strasse bus depot, non-public station
Main partners:	BVG, Total Deutschland GmbH, Linde
Funding:	European Commission, 5th Framework Programme
Operator:	Total Deutschland GmbH
Available fuels:	CGH_2 at 250 bar, produced on-site through electrolysis
	17,600 l LH_2 at 3-4 bar and –253°C, shipped in by Linde

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Berlins first hydrogen filling station: The Hydrogen Competence Centre (II)

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Operation of a hydrogen powered 12m standard bus (I)

Make:	MAN Nutzfahrzeuge AG
Propulsion:	Hydrogen ICE, 140 kW (first generation)
Fuel:	CGH_2 at 300 bar
Commissioning:	29 April 2004
End of test phase:	22 November 2004
Technical breakdowns:	none

The bus was operated on different scheduled service routes and during special events.

Operation of a hydrogen powered 12m standard bus (II)

Mileage	3,929 km
Fuel consumption	16.5 kg/100 km
Energy costs (H_2)	95.70 EUR/100km (5.80 EUR/kg)
Energy costs (Diesel)	44.00 EUR/100km (0.94 EUR/l)
Factor	Currently about 2.2 times higher energy costs for hydrogen

Operation of a hydrogen powered 12m standard bus (III)

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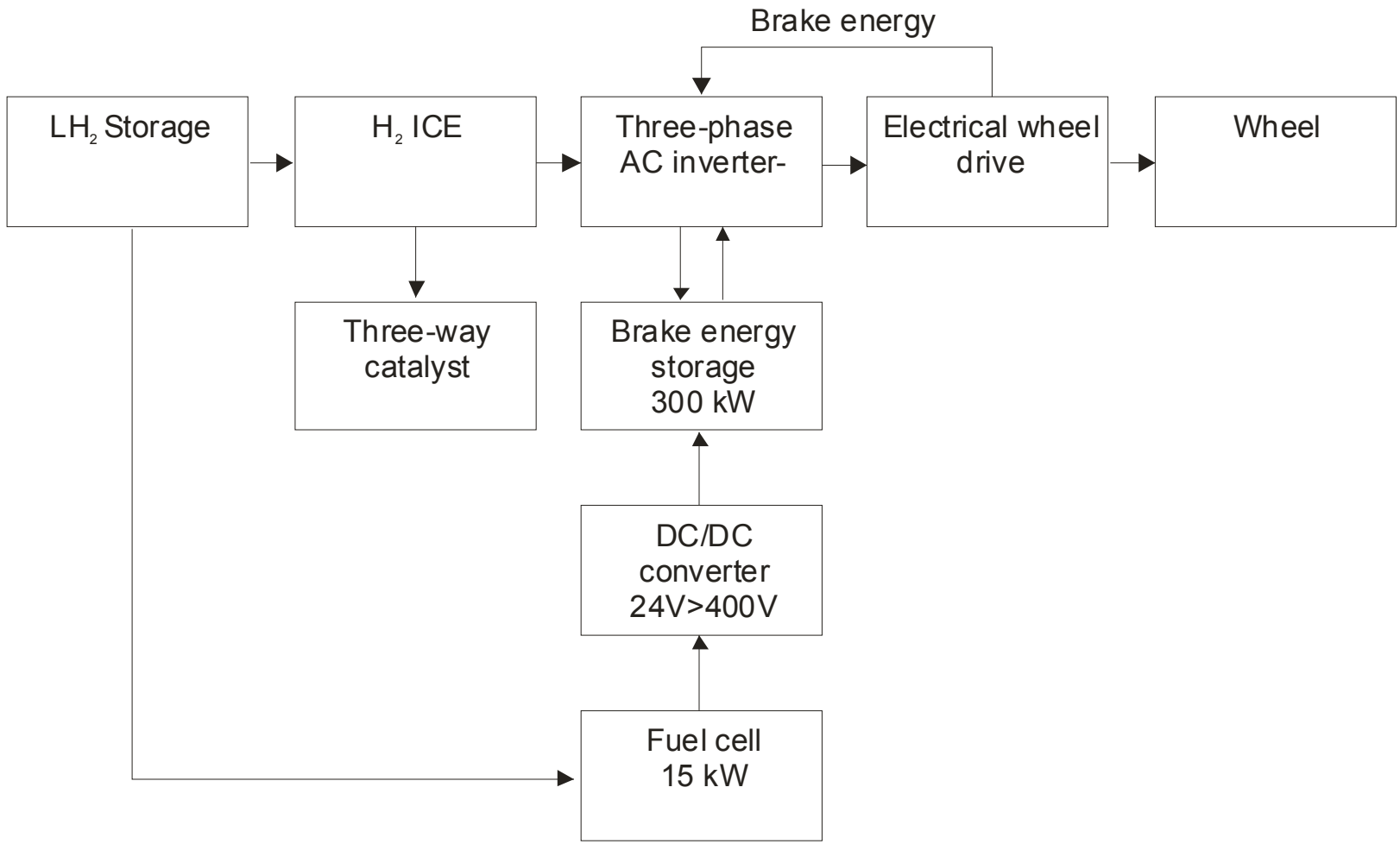
Construction of an articulated bus with hydrogen ICE, fuel cell and energy storage for Berlin (I)

Funding:	German Federal Ministry of Economics and Labour
Project duration:	2001-2006
Basic vehicle:	Mercedes O405 GNTD
Propulsion:	Electrical wheel drive
Fuel:	LH_2
Commissioning:	Spring 2006

The bus will be operated on different scheduled service routes and during special events.

Construction of an articulated bus with hydrogen ICE, fuel cell and energy storage for Berlin (II)



Construction of an articulated bus with hydrogen ICE, fuel cell and energy storage for Berlin (III)

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BVG as partner in the “Clean Energy Partnership Berlin”

Funding:	German Federal Ministry for Transport, Construction and Housing
Project duration:	2003-2007
BVG’s activities:	Implementation of a workshop for hydrogen buses at the Usedomer Strasse depot
	Operation of available vehicles under the umbrella of this project (vehicles and operation not funded)
	Promotion of hydrogen as a fuel in public transport

BVG as a partner in “HyFleet:Cute”

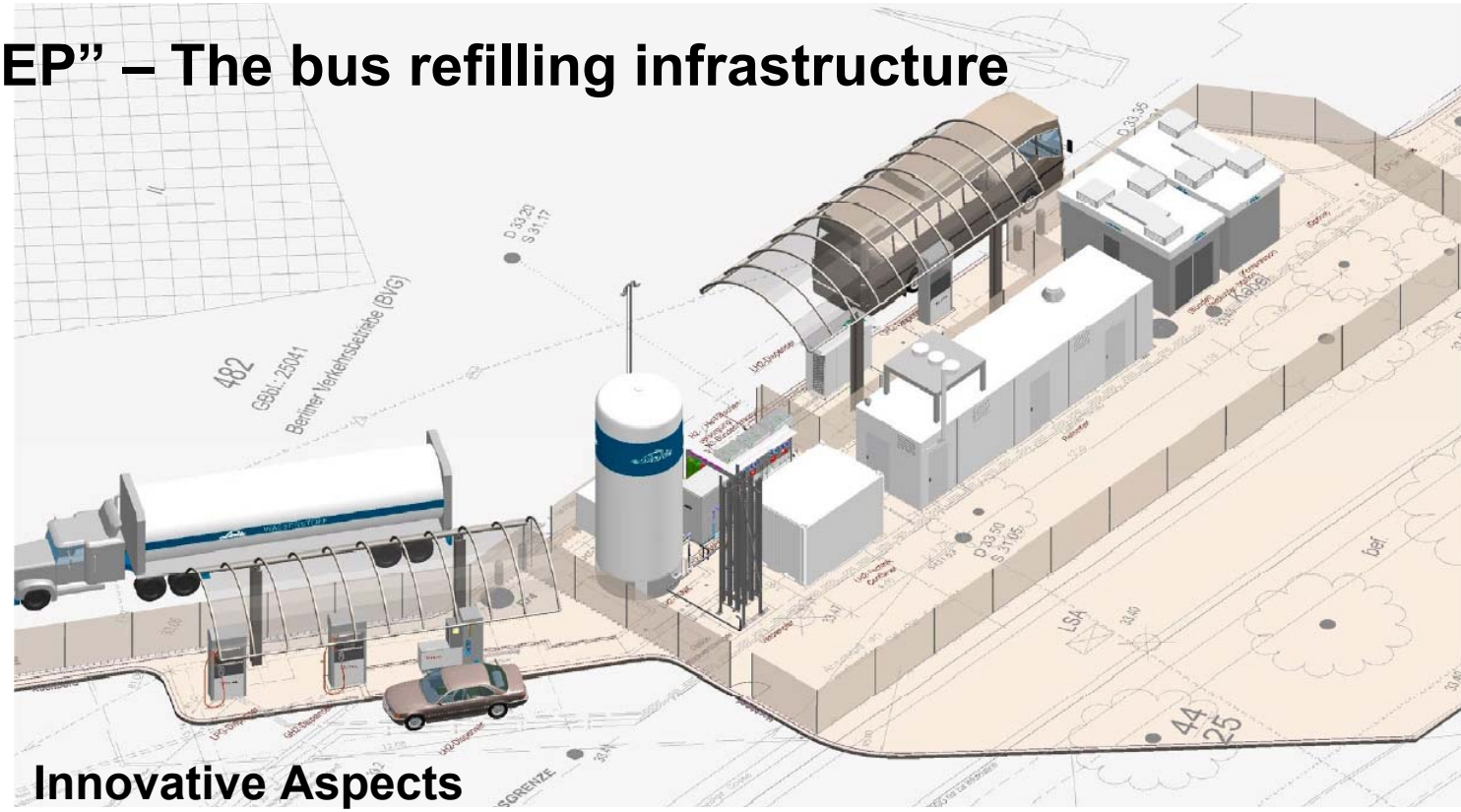
Funding:	EC, 6th Framework Programme
Expected project duration:	2005-2009
Vehicles in Berlin:	4 MAN buses with naturally aspirated hydrogen ICE, 150 kW (second generation) 9 MAN buses with turbocharged/direct injection hydrogen ICE, 200 kW (third generation) 1 MAN bus with turbocharged/direct injection hydrogen ICE, 200 kW, with energy management/FC-APU
Commissioning:	First vehicles are expected to be in operation starting from the FIFA World Cup 2006

“HyFleet:Cute” / “CEP” – The bus refilling infrastructure

- Total Deutschland GmbH started implementation of the third Berlin hydrogen filling station at Heerstraße in Berlin-Spandau in August 2005
- Activities at this site are funded within the HyFleet:Cute project and to a smaller extent within the CEP project

“HyFleet:Cute” / “CEP” – The bus refilling infrastructure

- A public part of the filling station can serve cars operated within CEP while a private part on the bordering BVG depot will serve BVG‘s hydrogen bus fleet
- A new bus workshop in this location will be part of BVG’s activities



Innovative Aspects

- Filling capacity of up to 20 buses / day
- CGH2 on-site production through reforming LPG or Bio-DME
- Reliquefaction of LH_2 boil-off
- New generations of dispensers and compressors using ionic fluids

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Hydrogen capital Berlin

H_2 filling station Usedomer Straße
H_2 bus workshop
(BVG depot / non-public)

H_2 filling station Heerstraße
H_2 bus workshop
(Total / public, Inauguration: October 2005

H_2 filling station Messedamm
H_2 car workshop
(Aral / public)

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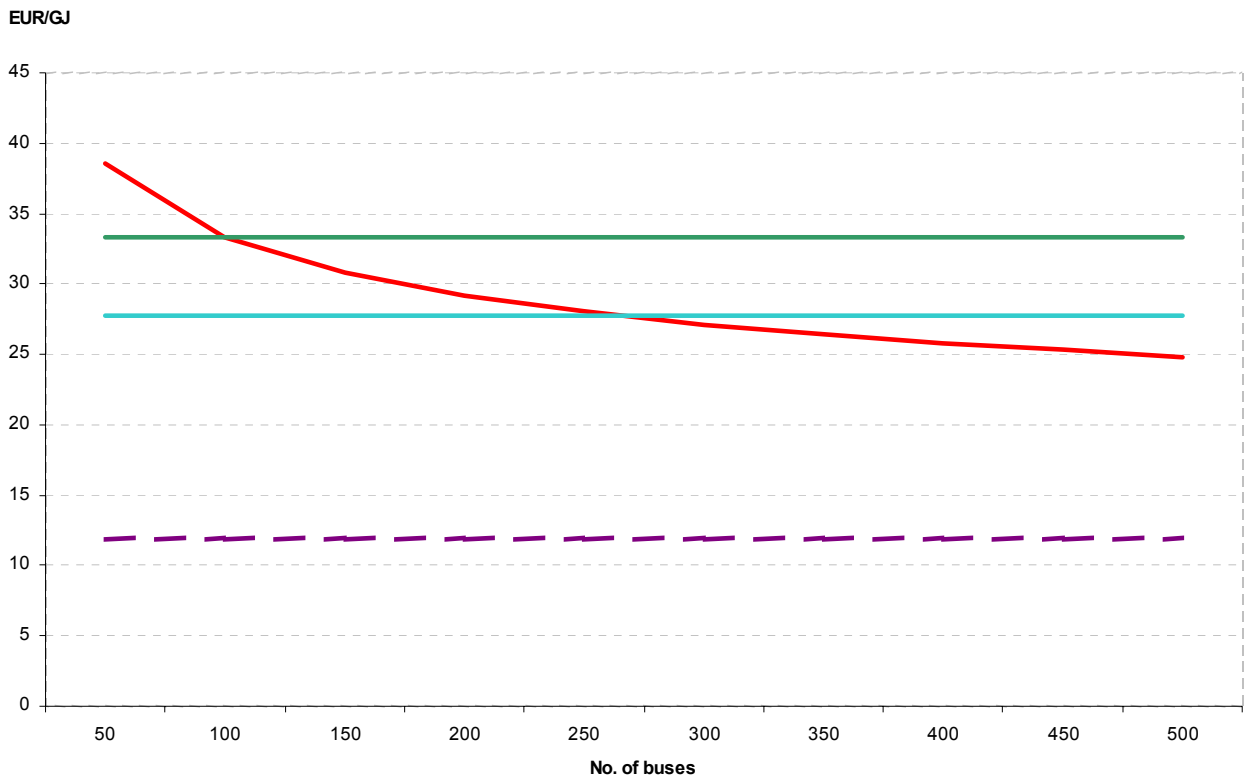
Development of hydrogen costs in dependency of consumption



Diesel price 1.20 EUR/l

Diesel price 1.00 EUR/l

On-site reforming of CGH_2 from natural gas

Diesel price excluding taxes (Basis: 1.20 EUR/l of which approx. 0.75 EUR/l taxes)

Source: TOTAL

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Outlook

Step 1: H2 ICE (2004 ...)

- Very high reliability ...
- ... good economic efficiency (competitive vehicle prices, increasingly attractive fuel costs) ...
- ... high power density and sufficient operating range
- A perfect moment for leaving the demonstration laboratories by entering into fleet operation under real life conditions.

Step 2: H2 ICE / FC hybrid (2006 ...)

- Basic driving power will still come from hydrogen ICE – with proven reliability and optimised engine efficiency - ...
- ... however, FC APUs in sophisticated hybrid concepts and brake energy recovery systems will further increase the overall system efficiency.

Step 3: H2 FC (2008 ...)

- While fuel cell vehicles have so far not proven to be reliable enough to be operated in a normal scheduled service they may initially be an option in special vehicles such as …
- … buses with optical guidance systems (“bus trams“) being a compromise between the flexibility and cost efficiency of buses and the transportation capacity of trams