

Status Fuel Cell Buses and European joint procurement



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Clean Transport Strategy

- Emission reduction targets:
-40% by 2020 / -80% by 2050
- As second largest city in Germany role model for sustainability and climate protection
- German center of wind-industry, headquarters of all major OEMs in Hamburg
- Continuous growth of the city requires emission cuttings and the reduction of congestion
- Early conversion to green and innovative solutions maintain the competitiveness of the local industry
- Hamburg as green city („European Green Capital“) also attracts new businesses and added value



Why Electric Buses?

Clear political commitment

- From 2020: Only emission-free buses to be purchased by HOCHBAHN

Long term strategy

- Early preparation to ensure attractiveness and performance capability of buses in the future
- Use of buses up to 14 years: 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



Bus Operation

“Innovation line” 109

- Distance: 10 km (central station - U Alsterdorf)
- Concept: exclusive use of innovative buses
- Operation of PHEV as well as BEV and FCHB
- Recharging infrastructure at both end stops

Criteria for the selection of line 109

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



Innovation line 109 – Vehicle use

Vehicles with combustion engine:

- Diesel-electric hybrid buses (serial and parallel: 12m / 18m)
- Plug-in buses with option for pre- and recharge (depot and first as well as last bus stop)
- Reference vehicle: Diesel bus Euro VI

Pure electric-drive vehicle:

- Fuel cell hybrid buses (12m)
- Battery buses with fuel cell as range-extender (18m)
- Battery bus (from 2016; 12 m)



- Acquisition and evaluation of data as a basis for further development steps together with the Fraunhofer Institute for Transportation and Infrastructure Systems (IVI):
 - consumption data
 - availability data
 - operating times , operating performance
 - ...
- In-depth accompanying study together with ika - Institute of Automotive Engineering at RWTH Aachen University
- Further investigation together with IVI and the University of Applied Sciences (HAW): evaluation of the use of electric buses with decentralized charging infrastructure at HOCHBAHN

Innovation line 109 – First operational experience

- Until now, only buses in focus of monitoring – from now on system approach
- Experience of drivers as well as operational management has immense impact on success of the operation
- Expenditures for staff trainings and control functions initially underestimated
- Complexity of system needs to be able to be „mastered“ by the driving staff (challenges in terms of quality of the staff in the future)

Operational planning and duty rostering

- No basic change in the tour planning
- Most of the parameters for individual shifts remain
- Usual linkage with other lines in one shift avoided on line 109
- Mostly unchanged turn around times/break times
- Specific planning parameters for FC, plug-in buses and, in the future, pure e-buses
- Consequently, more staff is needed due to the increasing number of tasks
 - Plug-in: Continuous safeguarding of sufficient turn around times for charging (also after the beginning and before the last tour)
 - Fuel Cell: Integration of a daily fueling tour to the hydrogen refueling station in the tour planning (from 2020: new refueling station and depot)

Why engage with fuel cell buses?

Co-financing opportunities & regional strategy

- The purchasing costs of fuel cell buses have decreased by more than 50% since the first generation, however they are still expensive; the main driver for cost reduction is expected to be volume through economies of scale
- A combination of European, national and local funding is key to finance these projects
- The regional aspect can be a key driver to invest in the technology - e.g. availability of by-product hydrogen or large amount of renewable energies in need for storage solutions in the region



Happy customers and bus drivers

- The technology is almost silent and offers additional comfort to passengers and bus drivers: lack of vibration, smooth drive
- Offers an improvement in the working environment of bus drivers – e.g. health, better customer relations, no range anxiety and full flexibility
- Reputational benefit for operators – seen as a clean, modern company at the forefront of innovation



Where are fuel cell buses in Europe today?

Over 90 fuel cell buses in operation or about to start operation, next large scale procurement of fuel cell buses under way

EU-funded fuel cell bus projects

- CHIC** ●
- ✓ Aargau, CH 5 FC buses (2011)
 - ✓ Bolzano, IT 5 FC buses (2013)
 - ✓ London, UK 8 FC buses (2011)
 - ✓ Milan, IT 3 FC buses (2013)
 - ✓ Oslo, NO 5 FC buses (2013)
 - ✓ Cologne, DE* 4 FC buses (2011/2016)
 - ✓ Hamburg, DE* 6 FC buses (2011/2016)

- High V.LO-City** ●
- ✓ San Remo, IT 5 FC buses (2016)
 - ✓ Antwerp, BE 5 FC buses (2015)
 - ✓ Aberdeen, UK 4 FC buses (2015)

- HyTransit** ●
- ✓ Aberdeen, UK 6 FC buses (2015)

- ✓ Countries with (upcoming) fuel cell buses
- ✓ In operation
- ✓ Planned operation
- (2015) Operation start/planned start
- * Co-financed by regional/national funding



EU-funded fuel cell bus project

- 3Emotion** ●
- ✓ Cherbourg, FR 5 FC buses (2017)
 - ✓ South Rotterdam, NL 2 FC buses (2017)
 - ✓ South Holland, NL 4 FC buses (2017)
 - ✓ London, UK 2 FC buses (2017)
 - ✓ Antwerp, BE 3 FC buses (2017)
 - ✓ Rome, IT 5 FC buses (2017)

Current national/regional-funded fuel cell bus projects

- ✓ Karlsruhe, DE * 2 FC buses (2013)
- ✓ Stuttgart, DE * 4 FC buses (2014)
- ✓ Frankfurt, DE * 1 FC bus (2016)
- ✓ Arnhem, NL* 3 FC buses (2017)
- ✓ Groningen, NL* 2 FC buses (2017)
- ✓ North Brabant, NL* 2 FC buses (2016)

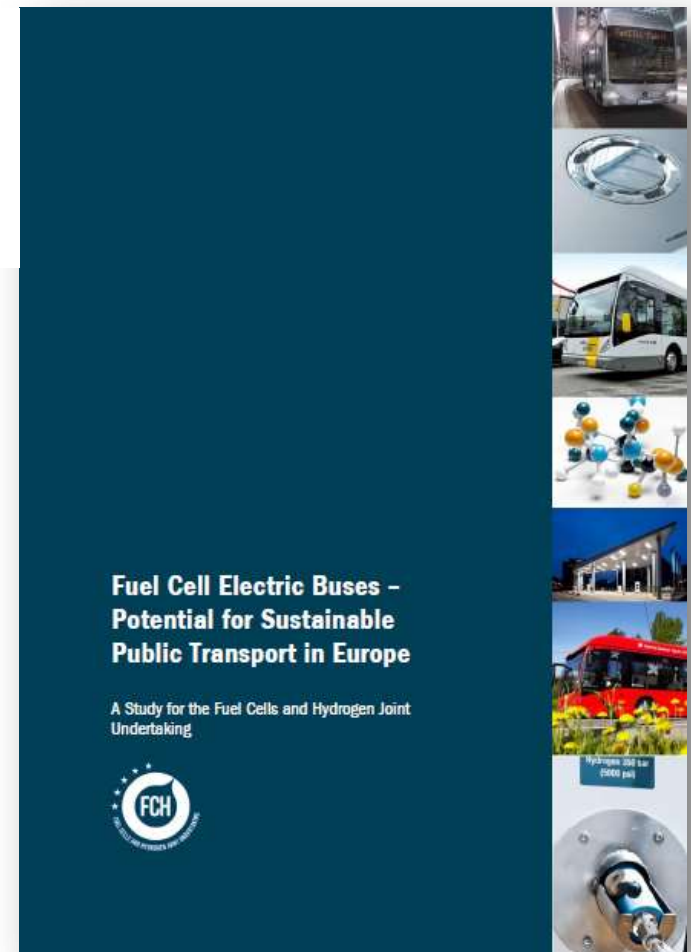
Last update: March 2016

The fuel cell bus study: a great potential for sustainable public transport in Europe



The fuel cell bus commercialisation study (published in September 2015) highlighted the great potential offered by fuel cell buses to address public transport needs

- The fuel cell bus coalition provided input to the FCH JU study
- The following steps to enhance the commercialisation of fuel cell buses are suggested:
 - Increase the number of fuel cell buses – to 300-400 in Europe by 2020
 - Continue work to reduce costs of buses (purchasing and maintenance costs) and hydrogen refuelling infrastructure
 - Engage with bus operators to deliver large-scale demonstration projects
 - Secure match funding from public sources



Purchase costs for fuel cell buses are expected to decrease significantly by 2030

- Two scenarios envisaged:
 - Fuel cell systems developed specifically for use in heavy-duty vehicles (“heavy-duty pathway” - HD)
 - Fuel cell systems developed for fuel cell cars adapted to buses (“automotive pathway” - AU)
- Results of the study show:
 - HD: The overall costs for FC buses are expected to decrease to a cost premium of 11-18% compared to diesel buses in 2030
 - AU: the costs for FC buses are expected to decrease even further, the FC bus purchasing price could reach ~ €320,000-€350,000 for a 12m bus
- The study also highlighted that a supportive regulatory framework for fuel taxation is needed to develop the commercialisation of fuel cell buses

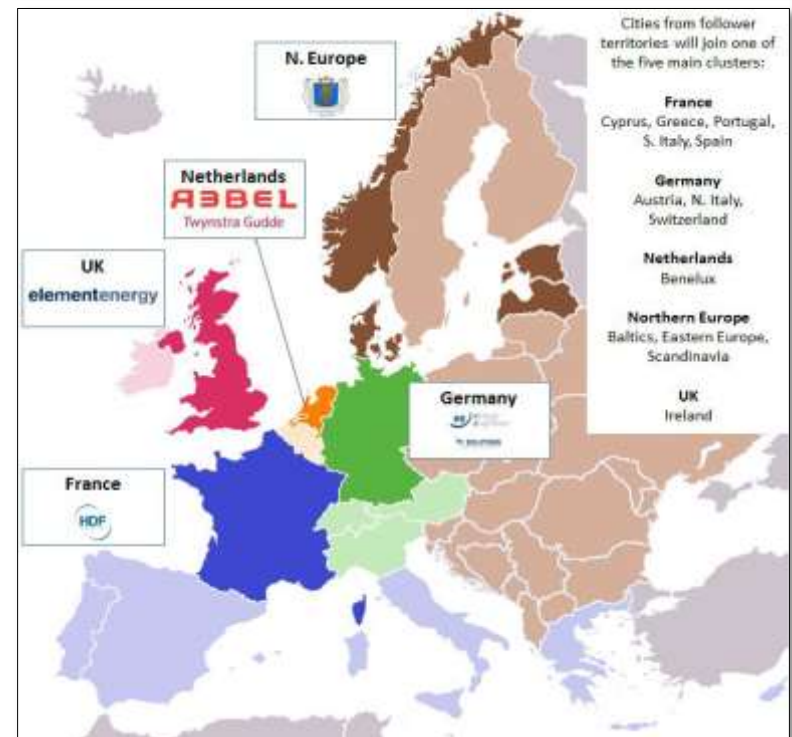
“Standard bus” in the framework of the study includes both 12 m and 13.5 m buses

Source: FCH JU study: “fuel cell electric buses: Potential for Sustainable Public Transport in Europe”, Sept. 2015

Joint Procurement Activities

FCH JU – bus commercialisation

- Letter of Understanding signed by five major European bus OEMs
- The FCH JU commissioned a consultancy team to carry out a project to coordinate the joint procurement of fuel cell buses across Europe
- Five clusters: France, Germany + North Italy, Benelux, Northern Europe and UK
- Vision: Develop a procurement program that will allow the deployment of hundreds of fuel cell buses across Europe before 2020



- JIVE will seek to deploy 142 hydrogen fuel cell buses and associated refuelling infrastructure across nine cities in five European countries.
- This project alone will more than double the size of Europe's fuel cell bus fleet (from ca. 90 by the end of 2016 to > 230).
- Economies of scale are expected to reduce the capital cost of fuel cell buses (to <€650k for a standard bus and <€1m for an articulated bus).
- Demand is being aggregated through joint procurement processes already underway, which are encouraging manufacturers to develop and refine their fuel cell bus offers.
- A campaign of monitoring and dissemination of the project results will ensure the lessons learned on the readiness of the project reach a target audience of bus operators and policy makers, with a view to expanding who can take action to expand the market for fuel cell buses.
- A second call is needed (in 2017) to allow fuel cell buses to be deployed in sufficient volumes to transition to a fully commercial offering from the 2020s (as described in the Fuel Cell Buses for Europe report - Roland Berger for the FCH JU, 2015).

>> potentially the first in a series of initiatives that could lead to the deployment of hundreds of FC buses in Europe by 2020

Infrastructure preparation

Hydrogen infrastructure on bus depot

- EU project framework: NewBusFuel

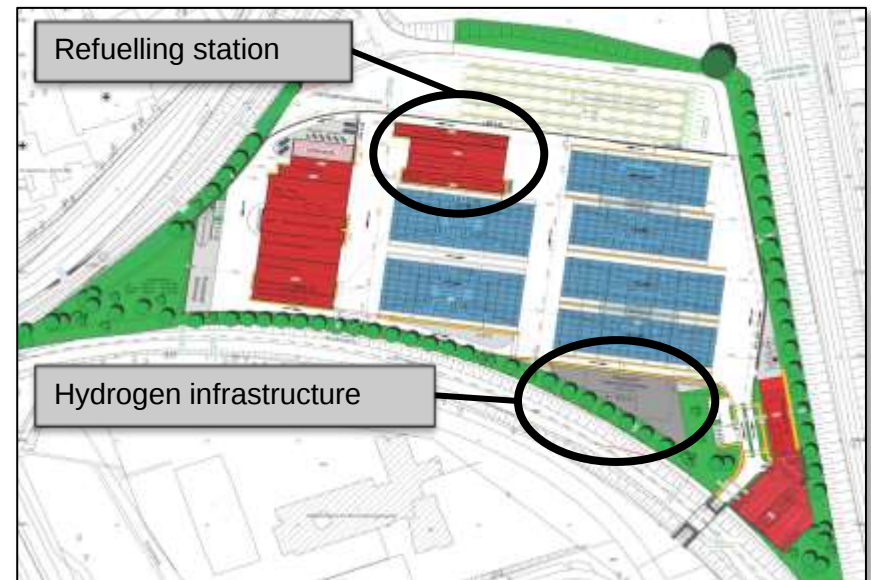


- Two studies for a new bus depot with 260 buses (1,400 m² reserved):

- Study 1: On-site production via PEM-electrolysis



- Study 2: Trailer delivery concept



Thank you!

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