Fuel Cell Electric Bus Projects – Status and Outlook from an Industry Perspective

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Topics

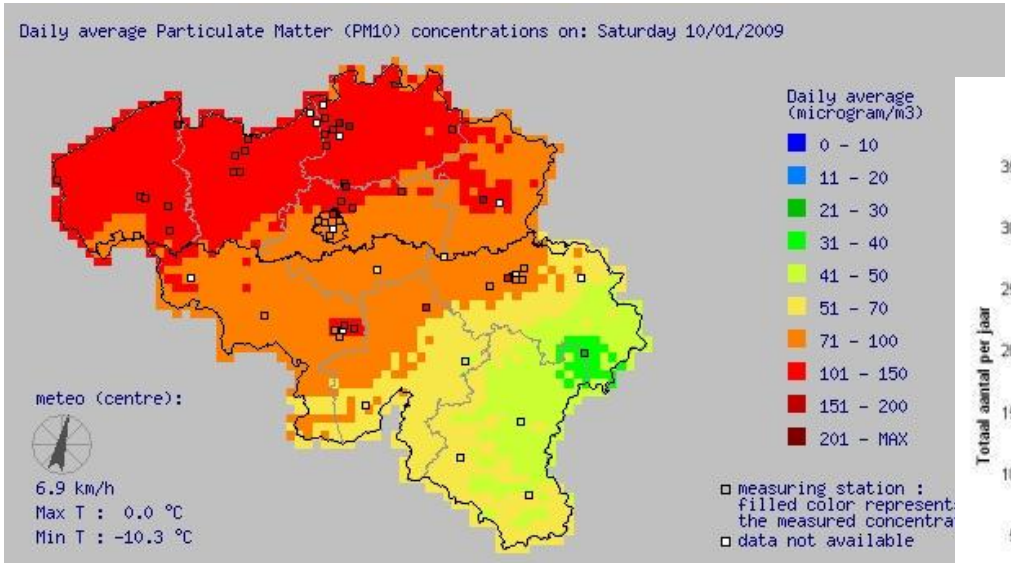
1. **Motivation and Commitment**
   - Limits of the Environment
   - Limits of Diesel Technologies
   - What are the options ?
   - Commitment from supply/demand side

2. **Accomplishments**
   - European (FCH JU) cofunded Projects
   - Present Status

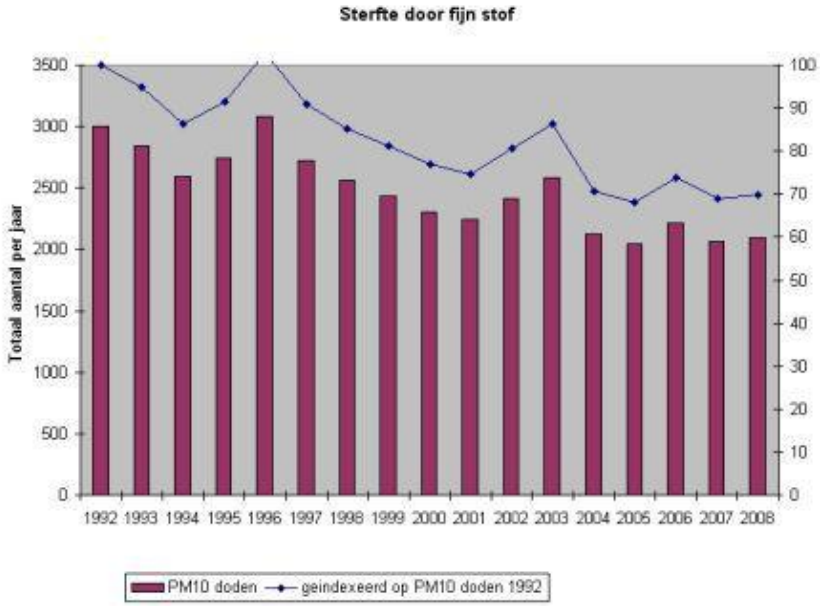
3. **Challenges and Opportunities**
   - Volume and Cost
   - Applications
   - What is next (2015 – 2020)

MOTIVATION AND COMMITMENT

Ultimate Limits of Air Quality



Exceeded Alloweed Air Quality Limits (33) in Belgium

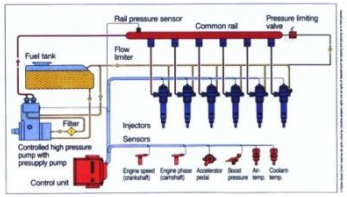


Deaths due to Air Quality (PM10)

Ultimate limits of Diesel Technologies

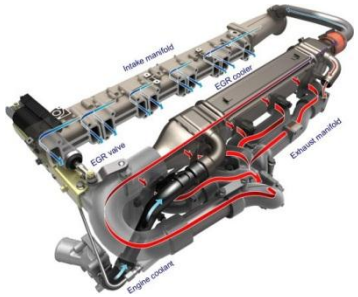
Injection Technologies

- High Pressure
- Common Rail Systems



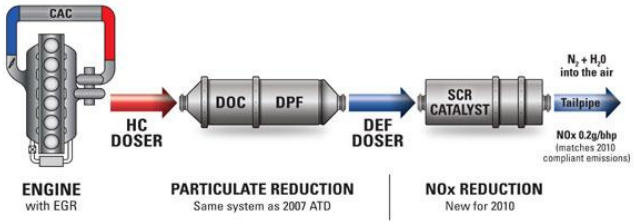
Cooling Technologies

- Low Flow Cooling (LFC)
- Air Injection (Lufteinblasung)
- EGR (Exhaust Gas Recirculation)
- NT Cooling (Niedertermperatur)



Aftertreatment Technologies

- CRT (Continuous Generation Trap)
- DOC (Denox Oxydation Catalyst)
- SCR (Selective Catalytic Reduction)
- EGR + SCR + CRT



Zero Emission Technology Options and TRL Levels

Inductively charged
Midibus
Brugge, Belgium
TRL 5 > 6

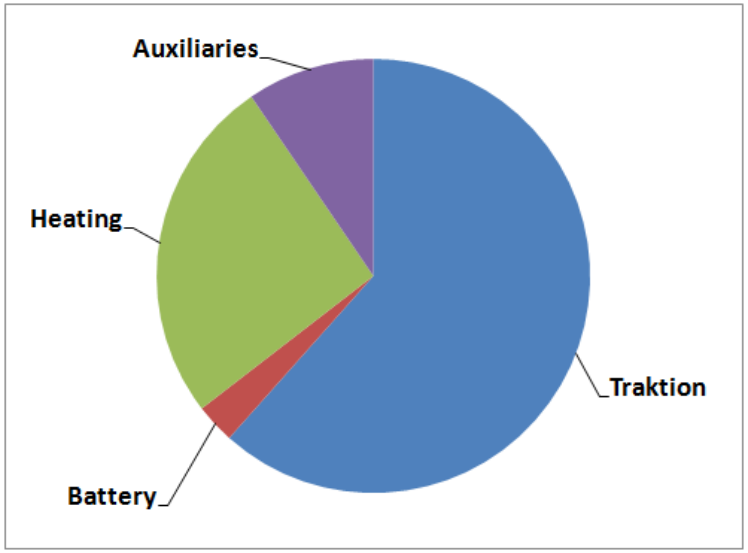
Electric Trolleybus
Parma, Italy
TRL 9

Conductively Overhead
Charged articulated bus
Geneva, Switzerland
TRL 4 > 5

Fuel Cell Electric
Antwerp, Belgium
TRL 7 > 8

Conductively Overhead
Charged 12m bus
Göteborg, Sweden
TRL 5 > 6

Battery and Fuel Cell are Complementary

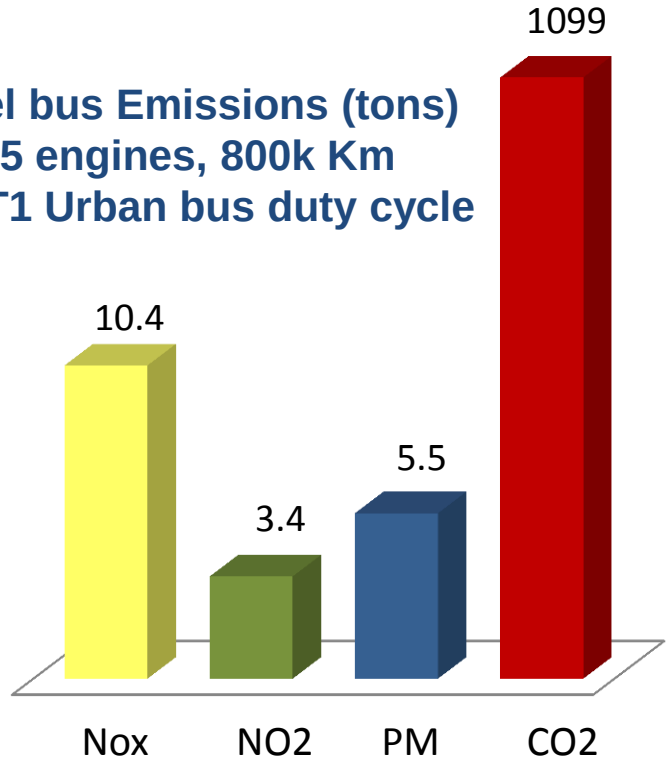


Fuel Cell Electric Buses show **1.8 kWh Energy per Km** travelled with
only about 60% for traction.
Battery ONLY would require **up to 540 kWh batteries** (without brake energy regen)
for a 300 Km duty cycle !!

Emission Savings in the real world

Consumption/Emissions per Mi !

Diesel bus Emissions (tons)
Euro 5 engines, 800k Km
SORT1 Urban bus duty cycle

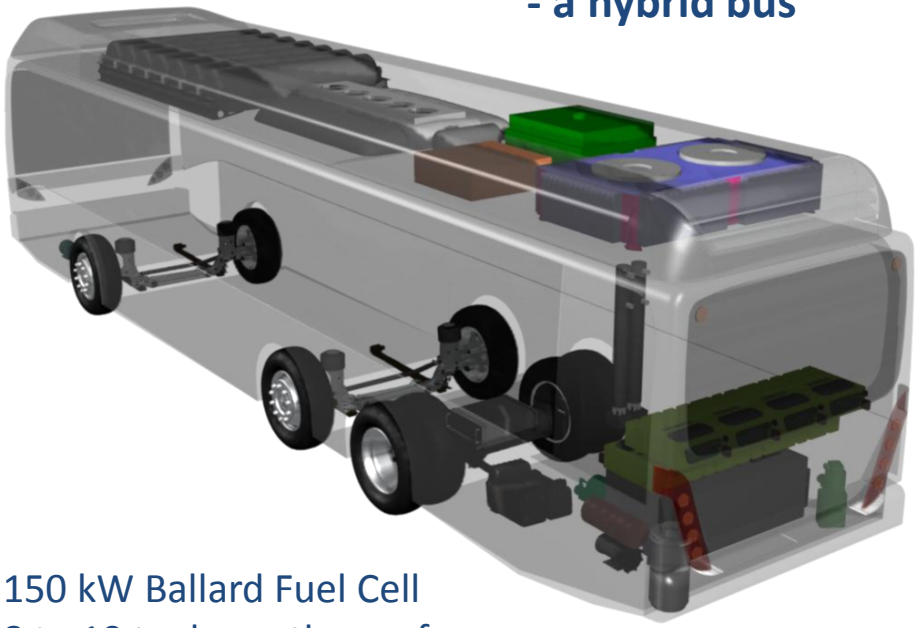


When Supply and Demand work Together

5 Bus OEM's have signed a MoU committing to develop fuel cell buses
Major Operators (London, Hamburg) and others have committed to buying them.

ACCOMPLISHMENTS

A fuel cell bus is : - a full electric bus
- a hybrid bus



150 kW Ballard Fuel Cell
8 to 10 tanks on the roof
LTO Batteries with cooling
Integration by bus OEM

FMEA Analysis
28° Side Tilt Test
European Whole Vehicle Type Homologation

Content and Status of FCH JU Projects

Topic	CHIC	High VLOCity	HyTransit	3EMotion
Number of buses	34	14	6	21
Number of HRS/HRI	5	2	1	3
Duration	2010-2016	2012-2018	2013-2018	2015-2019
Total budget (M€)	81	31.5	16.3	41
EU Contrib. (M€)	25.8	13.4	7	14.9
Status	In service	Start-up Q4/2014	Start-up Q1/2015	Start-up Q3/2016
Partners	25	12	8	14
Countries	9	6	4	6

TOTAL of 83 FC Buses in 9 Countries in 2016

Current EU-funded fuel cell bus Projects : 52 buses

CHIC

- ✓ Bolzano – 5 FC buses
- ✓ Aargau – 5 FC buses
- ✓ London – 8 FC buses
- ✓ Milan – 3 FC buses
- ✓ Oslo – 5 FC buses
- ✓ Cologne* – 4 FC buses
- ✓ Hamburg* – 4 FC buses

High V.LO-City (operation start planned for 2015)

- ✓ Sanremo – 5 FC buses
- ✓ Antwerp – 5 FC buses
- ✓ Aberdeen – 4 FC buses

HyTransit (operation start planned for 2015)

- ✓ Aberdeen – 6 FC buses

Current EU-funded fuel cell bus Projects : 21 buses

3Emotion (operation start planned for 2016)

- ✓ Cherbourg – 5 FC buses
- ✓ Rotterdam – 2 FC buses
- ✓ South Holland – 4 FC buses
- ✓ London – 2 FC buses
- ✓ Antwerp – 3 FC buses
- ✓ Rome – 5 FC buses

Current national/regional-funded fuel cell bus projects: 10 buses

- ✓ Karlsruhe * – 2 FC buses
- ✓ Stuttgart * – 4 FC buses
- ✓ Amsterdam * - 2 FC buses
- ✓ Groningen * - 2 FC buses

Aberdeen, Scotland
The largest EU fleet

Oslo, Norway

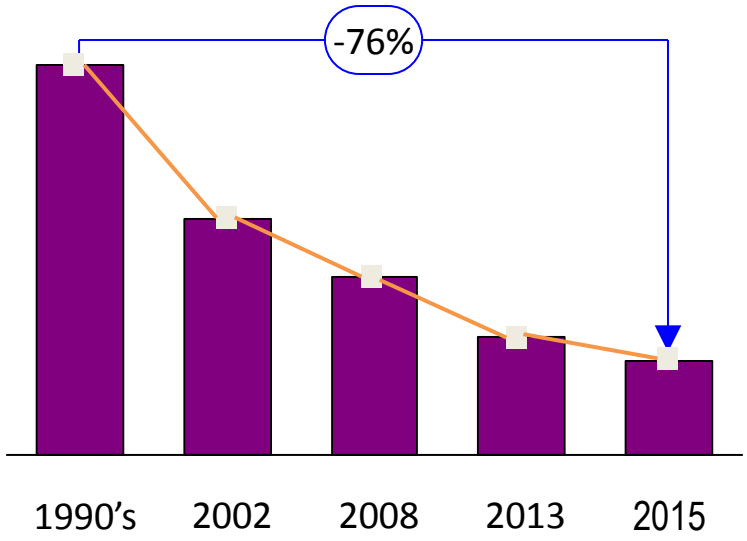
What have the PP Partnerships achieved ?

1. Technology works !
2. Large scale demos (From TRL 4 to TRL 7)
3. Availability climbing to acceptable level
4. Good Fuel Efficiency
5. Drivers and Passengers love them !

CHALLENGES
and
OPPORTUNITIES

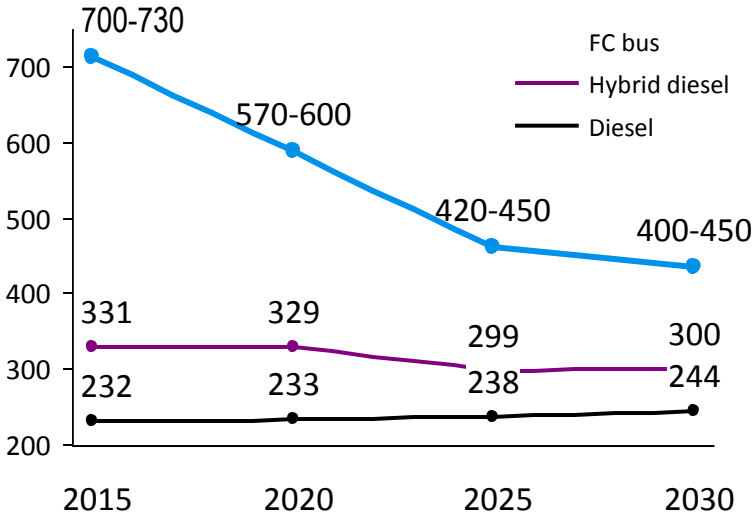
CHALLENGE 1 : FURTHER COST REDUCTION WITH VOLUME AND TECHNOLOGY

FC bus purchase price until 2015



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

Purchase price projection, solo FC bus
[EUR '000]



> **Price level reduction expectation in route for commercialisation of the technology**

Source : Roland Berger Consulting Services
Bus Commercialisation Study - Preliminary

CHALLENGE 2 : REGULATORY

Clean Vehicle Directive 2009/33 for public entitities:

- **Fuel consumption and Efficiency**
- **CO2**
- **Emissions (NOx, NO2, PM, CO)**
  - **No step change effect (50k € for Zero Emissions)**
  - **No penalties**

Needs review and compulsory implementation !!

Next Generation Bus Rapid Transit Fuel Cell Bus

Emerging Conclusions :

- Fuel cell buses are the most mature zero emission technology offering the same operational flexibility of a diesel bus

- Fuel cell buses are not a competition to battery electric as the application will dictate which technology is most appropriate, once they reach maturity

- Additional price and TCO reduction needed to make it commercial
  - > Coalition Building needed to achieve aggregate volume
  - > Continued Public Funding Support necessary

- Strong Commitment from Operators required – Not a walk in the park !

Thank you for your attention