FUEL CELL BUSES - AN UPHILL ROAD TO SUCCESS

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LIMITS TO THE ENVIRONMENT
Air pollution causes substantial environment and health impacts (2013):

- €330-940bn including €4bn healthcare costs
- 40m EU citizens are still exposed to PM10 levels above the EU limits!
- Transportation accounts for approx. 25% of GHG emissions

It is time we get these numbers into the equation! Burning Fossil Fuels in Traffic is no longer an option!
LIMITS TO DIESEL TECHNOLOGY

Injection Technologies
- High Pressure
- Common Rail Systems

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

Aftertreatment Technologies
- CRT (Continuous Generation Trap)
- DOC (Denox Oxydation Catalyst)
- SCR (Selective Catalytic Reduction)
EGR + SCR + CRT all together !!

Nothing short of an on-board chemical plant
Where are fuel cell buses in Europe today?

→ Over 90 fuel cell buses in operation/about to start operation + >100 bus project awarded

**Ongoing 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 (2011/14)

**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)

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

**Ongoing 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)
- 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 (2016/2017)
- Groningen, NL* – 2 FC buses (2017)
- Eindhoven, NL* – 2 FC buses (2016)

Last update: October 2016
FUEL CELL BUS FLEETS

New Programs in 2017 (142) and 2018 (150)

TOTAL by 2018 : min. 200

TOTAL mileage sofar :
- USA : over 3 million Km (since 2011)
- EU : over 8 million Km (since 2009) – 3 projects (CHIC, High VLOCity, HyTransit)

Fuel Economy : 8 kg/100 km

Availability : 85-92%

More than 30 major cities and regions in 13 Member States can’t be wrong !
ALTERNATIVE ZERO EMISSION TECHNOLOGIES

Inductively charged
TRL 4 > 5

Electric Trolleybus
TRL 9

Conductively Overhead
Charged
TRL 5 > 6

Fuel Cell Electric Bus
TRL 7 > 8

Only electric trolleybuses are time-tested
Only Fuel Cell Electric Buses have achieved highest Readiness Level
### MARKET SEGMENTS/PROPULSION

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>%</th>
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<tbody>
<tr>
<td>Midibus</td>
<td>11.4</td>
</tr>
<tr>
<td>Standard 12m</td>
<td>56.4</td>
</tr>
<tr>
<td>Artic 18m</td>
<td>26.5</td>
</tr>
<tr>
<td>Other</td>
<td>5.7</td>
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<table>
<thead>
<tr>
<th>Propulsion</th>
<th>Diesel</th>
<th>Bio-diesel</th>
<th>CNG</th>
<th>Biogas</th>
<th>Electric</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>79 %</td>
<td>9.9 %</td>
<td>7 %</td>
<td>0.6 %</td>
<td>1.2 %</td>
<td>2.3 %</td>
</tr>
<tr>
<td>Future (2025)</td>
<td>34 %</td>
<td>18.9 %</td>
<td>26.3 %</td>
<td>13.2 %</td>
<td>41.5* %</td>
<td>13.2 %</td>
</tr>
</tbody>
</table>

* incl. hybrids

Source: UITP Survey 3iBS 2013
**CO2 (W-T-W) FOOTPRINT in 2015 (kg/100Km)**


- Diesel: 122 kg/100Km
- H2 steam reforming methane: 106 kg/100Km
- H2 electrolysis grid electricity DE: 225 kg/100Km
- H2 electrolysis grid electricity UK: 201 kg/100Km
- H2 electrolysis grid electricity NL: 180 kg/100Km
- H2 electrolysis grid electricity FR: 31 kg/100Km
- H2 electrolysis grid electricity NO: 8 kg/100Km
- H2 electrolysis RES: 0 kg/100Km

Only Renewables will do! Let’s do it right. Time is running out.
BUS COST DEVELOPMENT
(Source: Fuel Cell Buses – Potential for Sustainable Public Transport in Europe – A study for the FCH JU by RB Strategy Consultants)

FC bus purchase price evolution

- So far, bus prices have decreased by **about 75% since 90s**
- Decrease 2010 – 2015 (to 2010 level) : **-35%**
- Decrease 2015 – 2020 (to 2010 level) : **-52%**

Price projection scenarios (x 1000 €)

- Price projections on following assumptions:
  - 2015-2020: niche (< 1000)
  - 2020-2025: scale (8-10,000)
  - 2025-2030: best case (10-20,000)
- Technological synergies with passenger cars show further cost-down potential (not depicted here)
REVOLUTION... NOW

(Source: The future for Clean Energy Technologies - Update Sept 2016 (DOE)

Cost reduction of renewables and fuel cell stacks in 2008-2015 time frame between 65% and 53%. On-target and a lot more to come before 2025.

Future Developments and Game changers include:
- Home-made hydrogen (for the car and the house)
- Cost of hydrogen less than diesel
- Platinum free fuel cells
- Solar-driven hydrogen production plants
- Policy mandates for zero emission vehicles in city centres
CONCLUSIONS

- Electric buses will be **mainstream in 2020 – 2025** time frame
- Battery and Fuel Cell Electric Buses will complement each other.
- Their share will be defined by the application and the cost factors (bus, H2 cost vs. infra)

- FCEB’s will have run **millions of kilometers** in trouble free daily service
- FCEB’s are **reliable, safe and easy to operate**
- FCEB’s offer **zero CO2 W-T-W transport** from day 1 !!

- FCEB’s do **NOT NEED** a network for refueling/recharging
- FCEB’s are **NOT limited** in their operation or use
- FCEB’s are **NOT subject** to expensive and dedicated infrastructure and charging systems
- FCEB’s will become affordable with **competitive TCO** (on level playing field terms)

FCEB’s are part of the future of transportation !!!!
Thank you for your attention

Please consult [www.fuelcellbuses.eu](http://www.fuelcellbuses.eu) website (on-line shortly) to learn more, including a self-assessment questionnaire for public transit stakeholders and PTO/PTA.