Fuel cell Electric Bus: It works and it’s ready!
Van Hool Today

► 70 Years Bus Experience (design, production, service)
► Family owned and managed
► 90% Exports Worldwide
► 4,450 Employees in two production facilities
► 1,200 Output Buses and Coaches yearly in 2 manufacturing plants
► Flexibility in Design and Market requirements
Range of Low Emission and Zero Emission Standard Bus Solutions

Electric
- A309

TROLLEY
- A330 T (IMC)
- AG300T (IMC)

HYBRID
- Diesel-electric
- A308 Hyb
- A300 Hyb
- AG300 Hyb
Range of BRT solutions on electric platform

EXQUiCiTY

18

24
Fuel Cell Bus
Range

A300L FUEL CELL USA
A330 FUEL CELL EUROPE
A330 FUEL CELL EUROPE
EXQUICITY18 FUEL CELL
NEW
## Operational Use of different Driveline Models

<table>
<thead>
<tr>
<th></th>
<th>Diesel Bus</th>
<th>Battery E-Bus Plug-in</th>
<th>Battery E-Bus opportunity charging</th>
<th>FVEB Fuel cell E-Bus</th>
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<tbody>
<tr>
<td>Range + 300 km</td>
<td></td>
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<tr>
<td>External Fueling/Charging</td>
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<tr>
<td>Incity Infrastructure</td>
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<tr>
<td>Zero Emission</td>
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Fueling up in 7 minutes…

The fuel cell bus brings the best operational solution.

<table>
<thead>
<tr>
<th></th>
<th>Fuel Cell</th>
<th>Trolley</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>High comfort</td>
<td></td>
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</table>

- **Fuel Cell**
  - High comfort

- **Trolley**
  - High comfort

- **Battery**
  - Low comfort
  - Medium comfort
  - High comfort
FCEV-Bus Experience
First Generation 2005

Fuel Cell bus,
Golden Gate
5 x CALIFORNIA
Cologne, Germany

London, England

Rotterdam, The Netherlands
**EU-funded FCB projects**

**CHIC**  (project over in 2016/buses still driving)
- 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* – 2 FC buses (2014)

**High V.LO-City**
- Antwerp, BE – 5 FC buses (2014)
- Aberdeen, UK – 4 FC buses (2015)
- Groningen, NL – 2 FC buses (2016)
- San Remo, IT – 3 FC buses (2017)

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

**Legend**
- Countries with (upcoming) FCB
- In operation
- Planned operation
(2015) Operation start/planned start
* Co-financed by regional/national funding sources

**EU-funded FCB projects**

**3Emotion**
- Aalborg, DK – 3 FC buses (2018)
- Pau, FR – 8 FC buses (2019)
- Rome, IT – 5 FC buses (2018)
- South Rotterdam, NL – 2 FC buses (2017)
- South Holland, NL – 4 FC buses (2018)
- Versailles, FR – 2 FC buses (2018)

**JIVE**
- Aberdeeen, UK – 10 FC buses
- Birmingham – 20 FC buses
- Bozen, IT – 12 FC buses
- Cologne region, DE – 30 FC buses
- London, UK – 26 FC buses
- Rhein-Main region, DE – 11 FC buses
- Riga, LV – 10 FC buses
- Slagelse, DK – 10 buses
- Wuppertal, DE – 10 buses

**Current national/regional-funded fuel cell bus projects**
- Karlsruhe, DE* – 2 FC buses (2013)
- Stuttgart, DE* – 4 FC buses (2014)
- Frankfurt, DE* – 4 FC bus (2017)
- Arnhem, NL* – 1 FC bus (2017)
- North Brabant, NL* – 2 FC buses (2017)

*Last update: Sept 2017*
Development Stages and References

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<td>6</td>
<td></td>
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<td><strong>Number Buses</strong></td>
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<td>16</td>
<td>1</td>
<td>22</td>
<td>21</td>
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<tr>
<td><strong>Fuel Cell</strong></td>
<td>UTC 1. Gen</td>
<td>UTC 2. Gen</td>
<td>Ballard HD6</td>
<td>Ballard HD6+</td>
<td>Ballard HD7</td>
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<tr>
<td><strong>Battery</strong></td>
<td>Ni-C-Cl Zebra</td>
<td>Ni-M-H</td>
<td>Li-Ion Enerdel</td>
<td>Li-Ion Enerdel</td>
<td>LTO Actia</td>
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<td><strong>Motor</strong></td>
<td>Siemens 2x85kW Elfa I</td>
<td>Siemens 2x85kW Elfa I</td>
<td>Siemens 2x85kW Elfa I</td>
<td>Siemens 2x85kW Elfa II</td>
<td>Siemens PEM Elfa II+</td>
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</table>

**1. gen. USA 2-axle**

**1. gen. Europe 3-axle**

**2. gen. USA 2-axle**

**2. gen. Europe 3-axle**

**3. gen. Europe 3-axle**

**3. gen. Europe 2-axle**

References:
- High VLOCity HyTransit Cologne
- 3EMotion JIVE
Homologation R107: 28° Side Tilt Test
Hybrid Traction Components – Current Offerings building on ever stronger supplier base

- **Fuel Cell Module Ballard HD85 (PEM: Proton Exchange Membrane)**
  - Heavy Duty Design (for severe applications)
  - High Pressure and Temperature for better longevity
  - Integrated Cooling circuits and anti-freeze protection
  - Remote Monitoring and Diagnose (Direct connection to Can-bus)

- **Traction battery LTO (Lithium – Titanat – Oxyd) 24 or 36 kWh**
  - Heavy Duty Battery pack, developed for hybrid city bus applications
  - Quick Energy Turnaround
  - Dedicated BMS (Battery Management System) and cooling

- **PEM (Permanent Magnet Motor)**
  - Siemens 160/200 kW
  - 3. Generation Electronics
  - Noise optimised
  - Less maintenance
Improving through monitoring

Fuel Consumption 13m. between 9 and 11 kg/100km
- Impact Traffic: medium (7 – 10 %)
- Impact Topography: medium (5 - 10%)
- Impact Driver: high (+10%)

Availability 13m
- Aberdeen (fleet +10): 86% (89-83%)
- RVK Cologne (small): 89%
Moving to large scale production

<table>
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<tr>
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<th>A330 FC 12</th>
<th>A330 FC 13</th>
<th>AG300 FC 18</th>
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<tr>
<td>height [mm]</td>
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<td>3420</td>
<td>3420</td>
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<td>2/3</td>
<td>3/4</td>
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<td>seating capacity</td>
<td>35</td>
<td>41/36</td>
<td>39/34</td>
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<td>boarding height [mm]</td>
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<td>wheelbase [mm]</td>
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<td>5110+1690</td>
<td>5790+6250</td>
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<td>front overhang [mm]</td>
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<td>rear overhang [mm]</td>
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<td>approach angle</td>
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<td>7°7'</td>
<td>7°7'</td>
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<td>departure angle</td>
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<td>7°7'</td>
<td>7°7'</td>
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<tr>
<td>turning radius [mm]</td>
<td>10800</td>
<td>12400</td>
<td>12000</td>
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<tr>
<td>tires</td>
<td>6x 275/70-R22.5</td>
<td>8x 275/70-R22.5</td>
<td>8x 275/70-R22.5</td>
</tr>
</tbody>
</table>
We Thank you for your kind Attention
Back-up slides
Current Product Offering 12m und 13m

13m 3-Axle (2. Axle steered)  |  41 Seated

12m 2-Axle 35 Seated

Low Floor or Low Entry

Low Floor
- **ZERO Emissions**: Savings compared to Euro 5 Diesel Bus (SORT1 - 800,000 km)
  - NOx: 10.4 T/Bus
  - NO2: 3.4 T/Bus
  - PM <2.5μm: 5.5 T/Bus
  - CO2: 1.099 T/Bus

- **Sustained Mobility thanks to IMMEDIATE and FULL use of Renewables**

- **Noise Emissions**:
  - Minus 3 and up to 6 dB(A) = LESS 2 x half perceived noise

- **Maximal Energy Efficiency thanks to**:
  - Brake Energy Regeneration
  - Redundant Energy goes to brake resistors and is re-used in bus heating;
  - Innovative Ventilation system

- **Safety**:
  - H2 Leakage detectors – Closing valves at each H2 tank
  - Automatic Fire Suppression System
  - Fuel cell only und Batterie only Modes
Van Hool Aftersales Service Concept

- **Common Objective**: Buses on the road
- **Extensive Support**:
  - Call Centre
  - Repair and Maintenance
  - Service On Location: Maintenance contract made to measure
  - Spare Parts Logistics
  - Product Training (at Factory level and locally)
  - Performance Monitoring

- **Aftersales Service Model**
  - Tier 1: Operator: Preventative Maintenance and Limited Repair Authorisation
  - Tier 2: Bus OEM: Diagnosis, Spare Parts Ordering/Supply – Technical Assistance
  - Tier 3: Engineering/Design: Concept – Problem Shooting

- **Präventive Wartung**: Maintenance Plan

- **Corrective Maintenance and Repari**: Repair Methods and Tools – Training - Documentation
Part of European Policies:

1. Extensive experience with European Projects: as coordinator, partners, supplier.
2. Member of Hydrogen Europe, Taskforce Hydrogen in Transport and Advocacy Taskforce Hydrogen
3. Member of Industry Panel JIVE Projects

Project Management:

1. Qualification and Submission of Proposal
2. Product Definition: Close DIRECT technical partnership with customer base <> Engineering/Production
3. Engineering: Product Development, Homologation, Documentation
4. Production: Vertical Integration and Flexibility
5. Product Inspektion during Build: Integration of traction and H2 components
EU Commission supports Fuel Cell Bus applications:

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
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<tbody>
<tr>
<td>TOTAL</td>
<td>90 in 2017</td>
</tr>
<tr>
<td></td>
<td>224 in 2019 (JIVE I)</td>
</tr>
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<td></td>
<td>350 in 2020 (JIVE II)</td>
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<td>OEMs</td>
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<td>REGIONS/CITIES</td>
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<td>FCH JU CONTRIBUTIONS</td>
<td>118M €</td>
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Cost Reduction Potential:
Volume, Technology Leaps, Standardised Driveline

Fuel Cell Bus Price evolution: 2 conclusions

Projections Cost reductions thru 2030 with following assumptions:
- Niche markets thru 2020
- Mass markets 2020-2030

Source: Roland Berger Consultants

Conclusion 1:
The price of the FC bus is declining rapidly.

Conclusion 2:
FC Bus continues to be compared with Diesel bus. This equation might become irrelevant.