

BALLARD[®]

PUTTING FUEL CELLS TO WORK

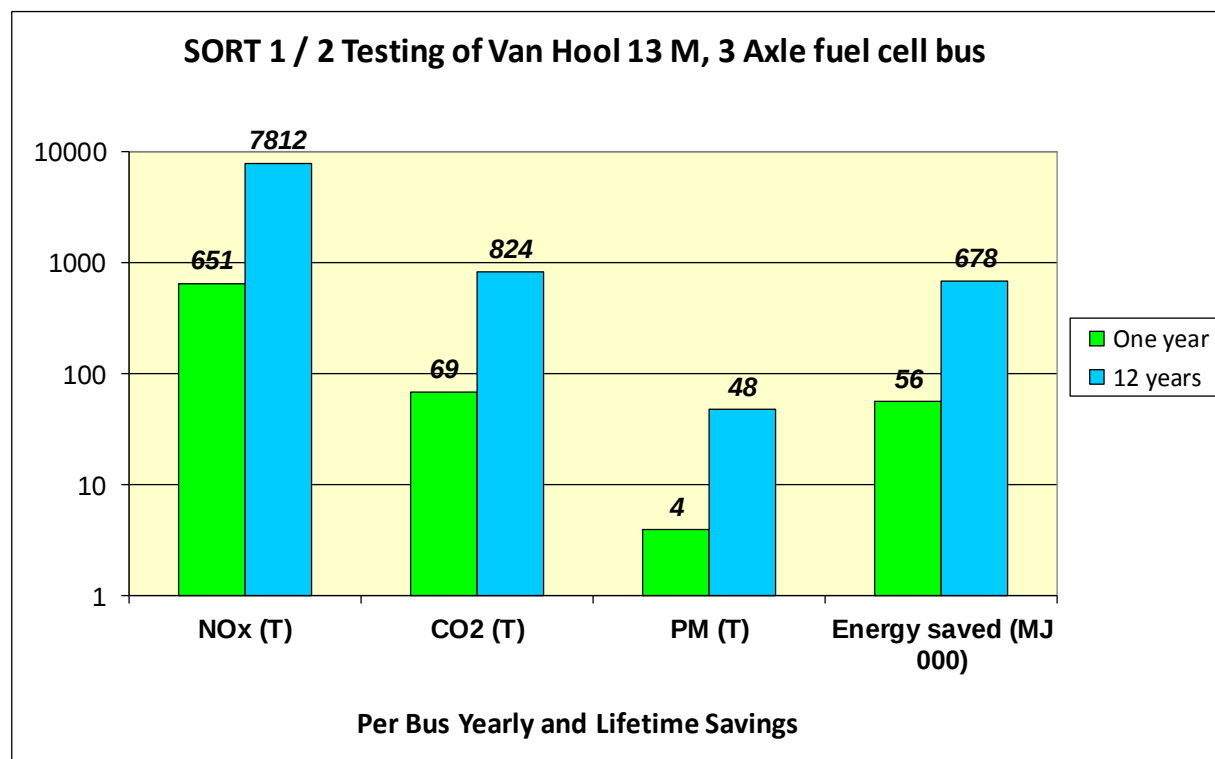
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eMobility – Fuel Cell Bus Perspective

Nov 18, 2014

Why Fuel Cell Buses – Emissions and Efficiency

- **Eliminates tailpipe emissions**
 - Nitrogen Oxides (NOx)
 - Sulphur Dioxides (SOx)
 - Particulate Matter (PM)
- **Greenhouse Gas Emission reductions**
 - Calculated on a well to wheel basis
- **Improved fuel efficiency**
 - 1.5-2.5x improvement over conventional diesel buses on an energy equivalent basis
- **Flexibility of operation**
 - No underground or overhead charging required



Source: Testing witnessed by TUV for 13 metre Van Hool fuel cell electric bus on SORT 1 & 2 drive cycles, dated June 24, 2013

Bus Program Evolution

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PHASE 1 - Proof of Concept
1991-1992
Vancouver, Canada



PHASE 2 - Commercial Prototype
1993-1995
Vancouver, Canada



PHASE 3 - Fleet Demonstration Alpha Sites
1996-1999
3 Vancouver, Canada & 3 Chicago, USA



PHASE 4 - Fuel Cell Engines Beta Sites
1999-2002
Palm Desert, USA



PHASE 5 - Serial Production
2002-2009
5 Continents, CUTE (30), Perth (3), California (3),
Beijing (3)



PHASE 6 – Hybridization of Fuel Cells
2009 - Current
40+ Canada\Europe\USA\Brazil

Fuel Cell Bus Experiences – European Deployments



Location	Fleet Size	Deployment Date
London	8 buses	2010
Oslo	5 buses	2012
Amsterdam	2 buses	2011
Cologne	4 buses	2011, 2014
Aberdeen	10 buses	2014
San Remo	5 buses	2013
Flanders	5 buses	2014
Hamburg	2 buses	2014

Recipient of the Busworld Ecology Award, in partnership with Van Hool, for demonstrating outstanding ecological credentials in fuel cell bus design



● Daimler FC buses

By mid-2014, a total of 40 Ballard-powered fuel cell buses will be deployed in Europe, with an additional 21 buses to be deployed in 2015

Why Fuel Cell Buses – Total Cost of Ownership vs GHG Projections

CO₂e/TCO (EUR/KM) COMPARISON OF STANDARD BUS POWERTRAINS

NOTE: RANGE ALSO SHOWS EFFECT OF ALTERNATIVE PRODUCTION SCENARIOS

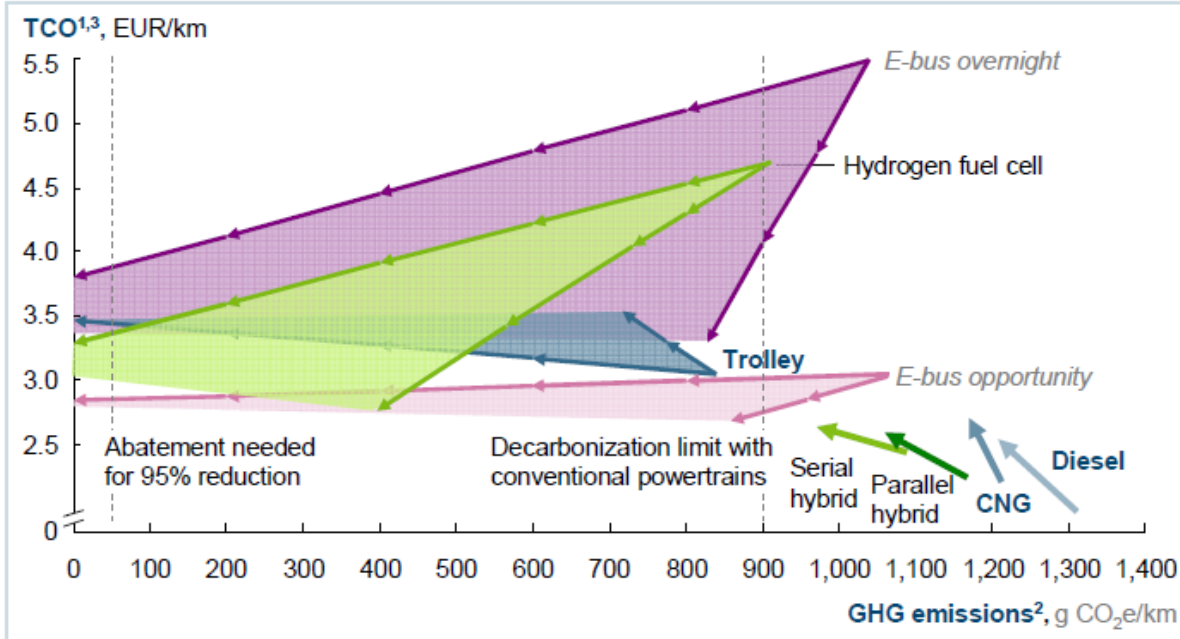
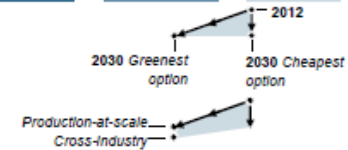
WELL-TO-WHEEL

12-M BUS

2012-30

Labelling of powertrain according degrees of operational experience (km driven)

- **Commercial solution (>>100 million km): conventional, trolley**
- **Test fleets (>1 million km): diesel hybrids, fuel cell**
- **Prototype phase (<10,000 km): e-buses**



1 TCO for a 12-m bus incl. purchase; running and financing costs based on 60,000 km annual mileage and 12 years bus lifetime

2 Total CO₂e emissions per bus per km for different fuel types from well-to-wheel

3 Electricity costs for e-bus and water electrolysis part of hydrogen production based on renewable electricity price with a premium of EUR 50/MWh over normal electricity

Source: Urban buses: alternative powertrains for Europe (McKinsey, 2012)

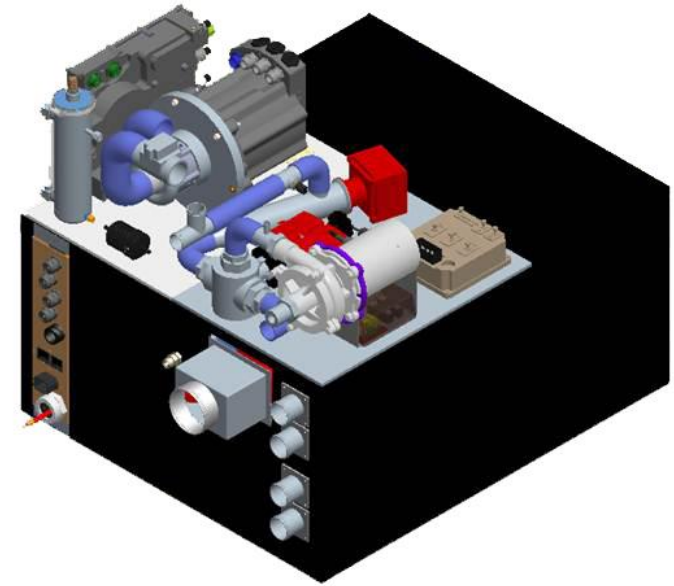
- Diesel, CNG, Serial & Parallel hybrid small GHG improvements with increase in TCO
- E-bus overnight unlikely to meet TCO and GHG targets
- Trolley is limited by catenary infrastructure
- E-bus opportunity limited proof of overhead/underground charging systems
- Fuel cell is the most promising technology projected to meet longtime GHG and TCO targets

Addressing Fuel Cell Cost – Next Generation (FCvelocity®-HD7)

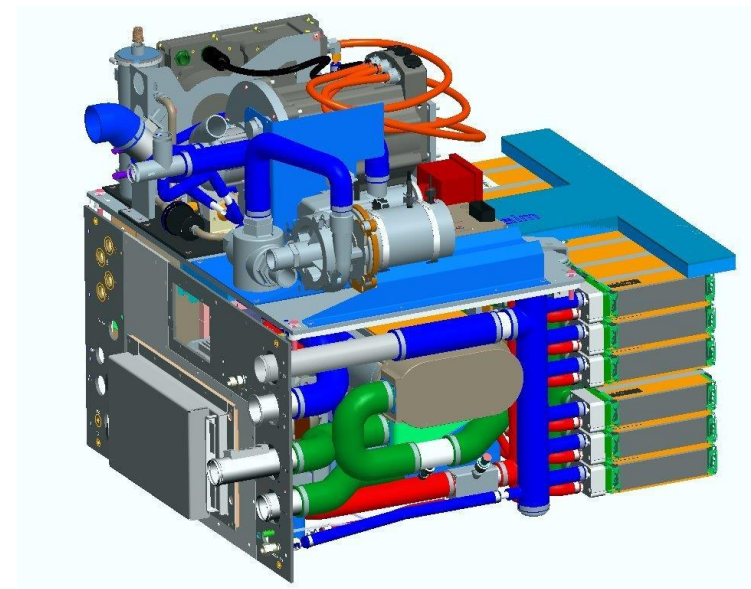
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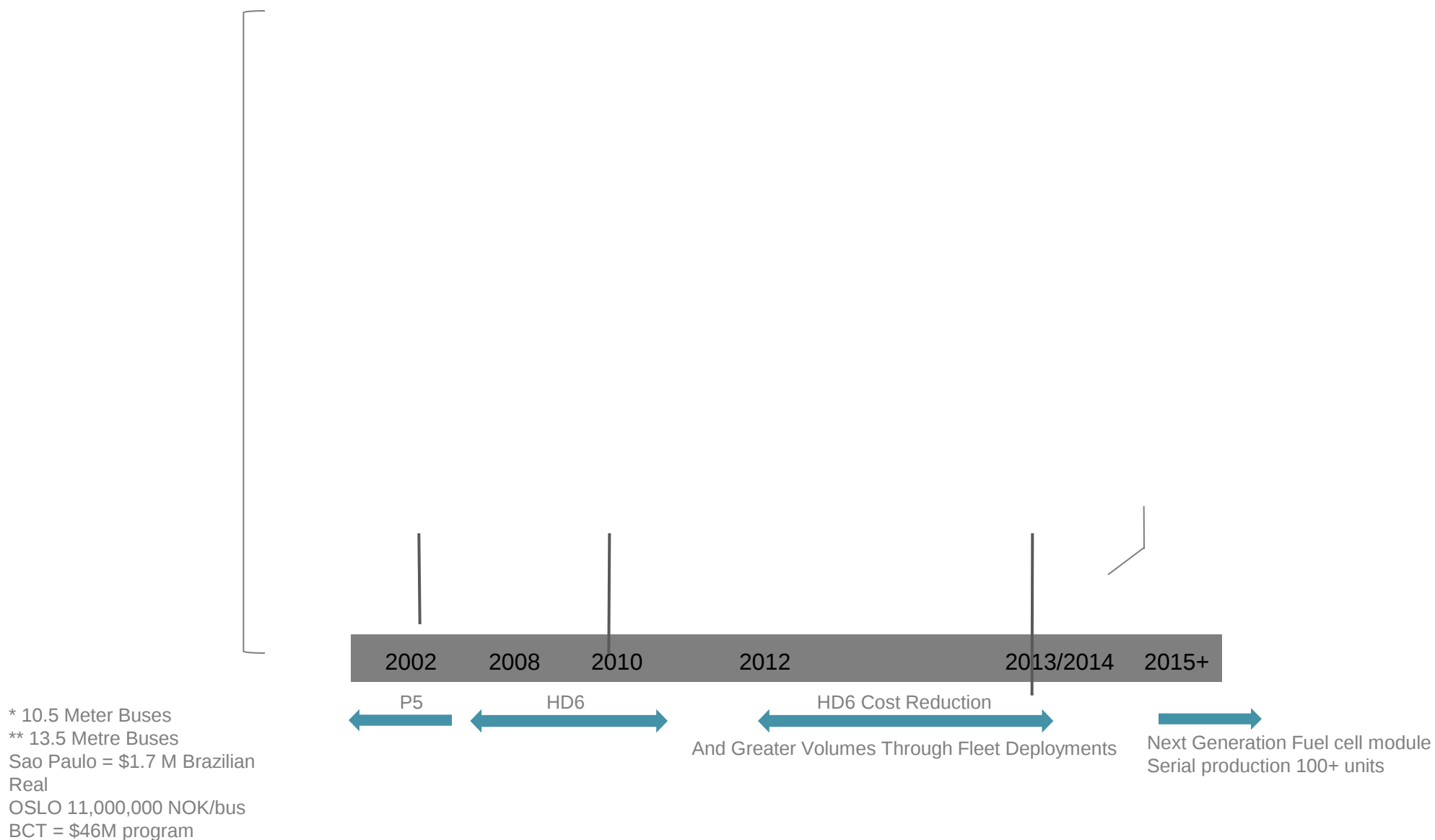
- **Next generation fuel cell bus module:**

- 100kW configuration available mid-2014
- 30-40% cost reduction
 - Latest generation fuel cell stacks – automated manufacturing and assembly processes
 - Reduced parts count – simplified humidification and resulting balance of plant
- Higher durability
- Fully integrated power module
 - Air compressor and coolant pump included
 - Integrated HRB motor controller (internally mounted)
 - Reduced preventive maintenance activities
- Module lifetime 10+ years
- Offered with a 15,000-hour warranty



FCvelocity®-HD7



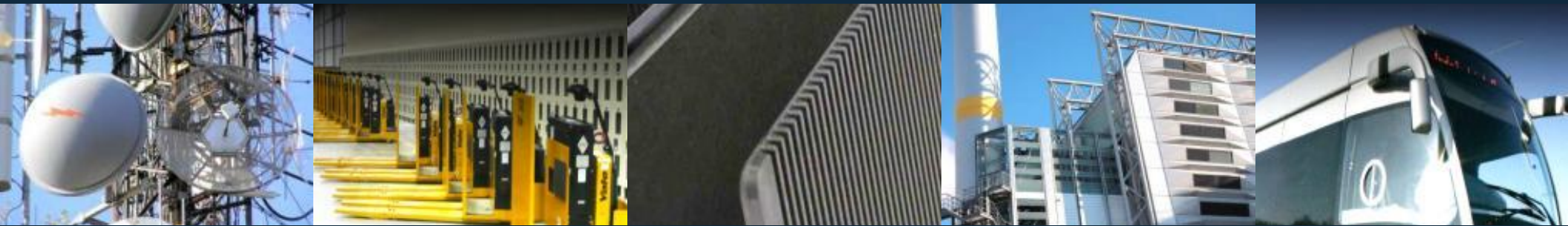


Addressing Fuel Cell Cost - Bus Power Module Product Evolution

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	2003: P5	2008: HD6	2011: HD6 V2	2014: HD7	201X: HD7 V2
Fuel Cell Lifetime: 4,000 hours demonstrated in service		10,000 hours demonstrated in BC Transit fleet	12,000 hours	>12,000 hours	>18,000 hours
Product Cost Reductions:		30% reduction •Leverages automotive volumes •Production environment •Direct material savings	15-20% reduction •Enhanced MEA to reduce warranty accrual costs	30-40% reduction •Automated MEA production •Common unit cell platform across products	

- **Fuel cell buses are electric buses**
- **Fuel cell buses are a proven platform to ensure reliable city transit operation**
- **Higher volumes and further design developments are already proving viability of this technology**
- **Locations with lower hydrogen cost will be the early mass scale adaptors**
- **Improvements in hydrogen generation and distribution will further help in mass scale adaptation of fuel cell buses**



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Thank You

