

40
years

BALLARD®

International Hydrogen Symposium: Fuel Cell Buses

Randy MacEwen, Ballard CEO
23 Oct 2019

The Ballard logo is displayed in white, bold, sans-serif capital letters on a dark blue rectangular background. The background of the entire slide is a futuristic digital highway with cars, binary code, and data visualizations.

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*“Mobility’s second
great inflection
point.”*

(McKinsey)

Why FC HDM?

- strongest value proposition
- lowest barrier to refueling infrastructure
- significant contribution to emissions reduction



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In Feb 2019, EU set emission reductions for Class 8 trucks, requiring reductions of 30% by 2030; expect extended to buses in 2022.

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Hydrogen fuel cell buses are electric buses.



Fuel cells enhance the performance of electric buses.

400-550km Proven range



Significant reduction in vehicle weight
(carry more passengers)



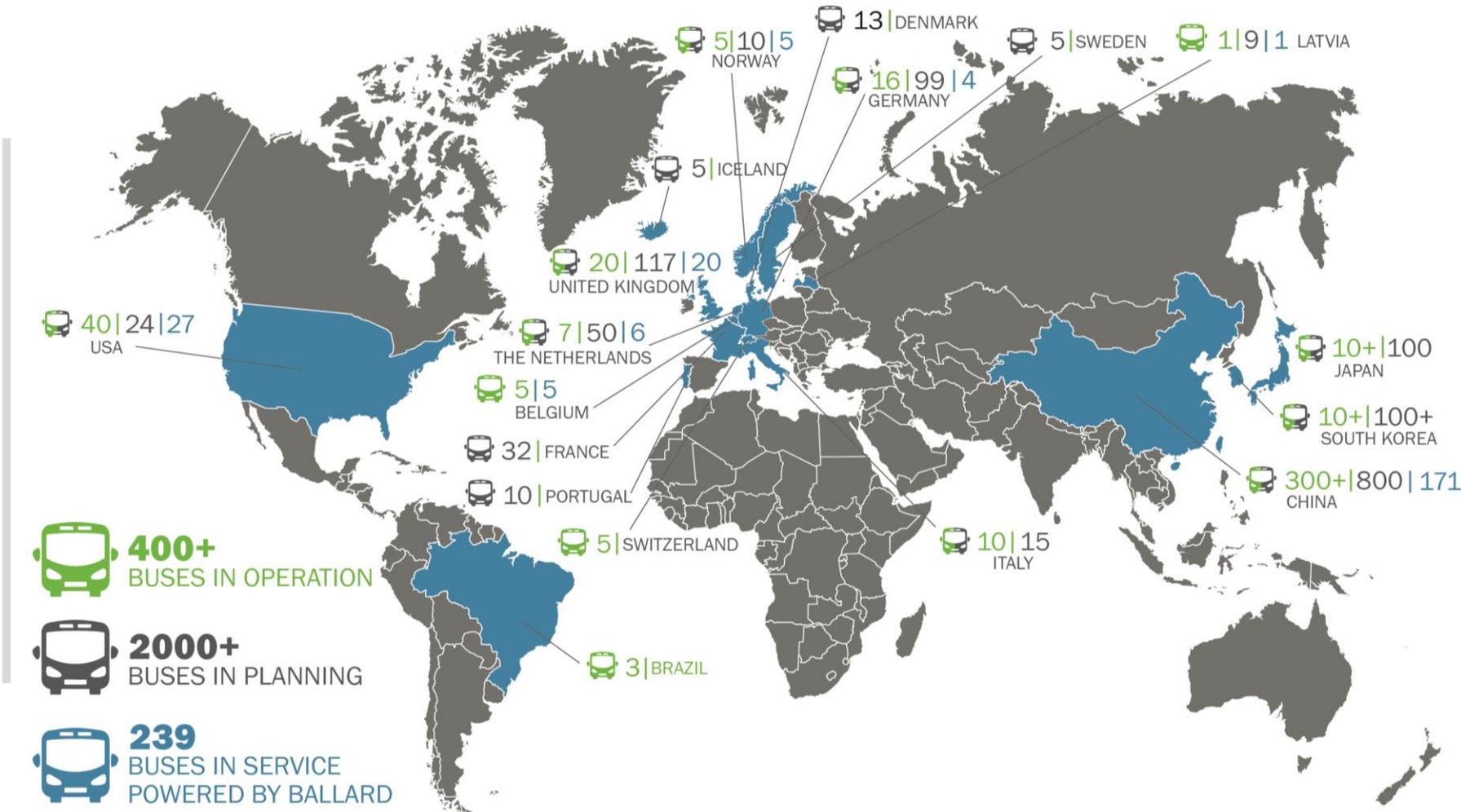
Rapid refueling speeds
(6 to 10 minutes)



1:1 replacement of conventional vehicles



There will be more than 2,000 FCEB on the road by 2020.





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FCEBs have demonstrated performance

- >20 years of road-experience
- >16 million km in service
- 237 buses in operation powered by Ballard
- Operation in challenging routes and climates

Performance of FCEBs

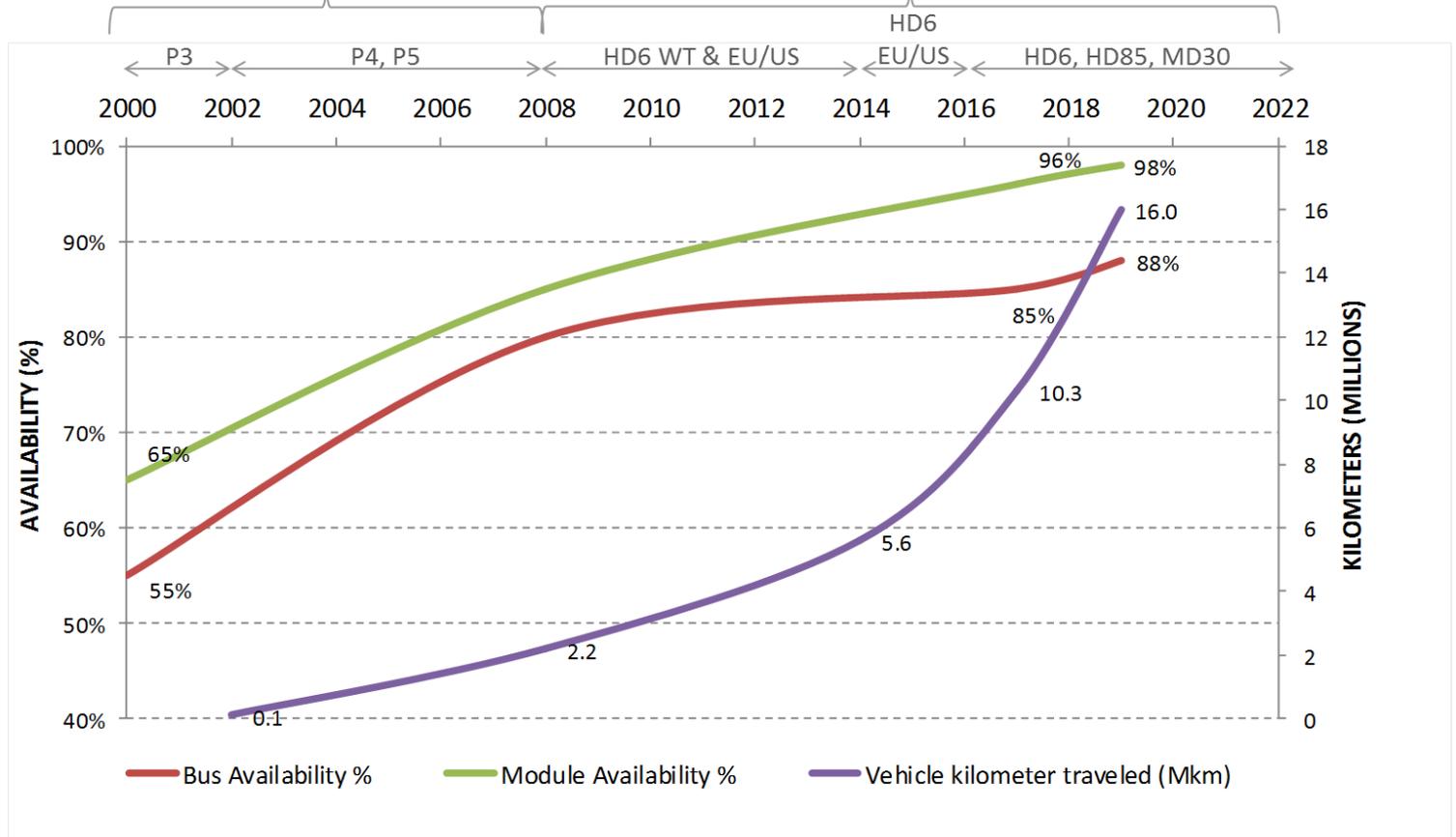
Based on bus fleet monitored by Ballard in 2018 and 2019

- ✓ Range: **up to 500 km** (depending on H2 storage)
- ✓ Fuel consumption: less than **8kg/100**
- ✓ Fuel cell stack durability: **> 30,000 hrs** (proven in service)
- ✓ FCEB current maintenance cost: **€0.30/km**
- ✓ Environmental conditions:
 - Fuel cell power systems operates from **-40°C to +50°C** ambient temperature
 - Next generation module will include freeze start from **-25°C**

Performance of FCEBs

100% fuel cell power

Battery/fuel cell hybrid power

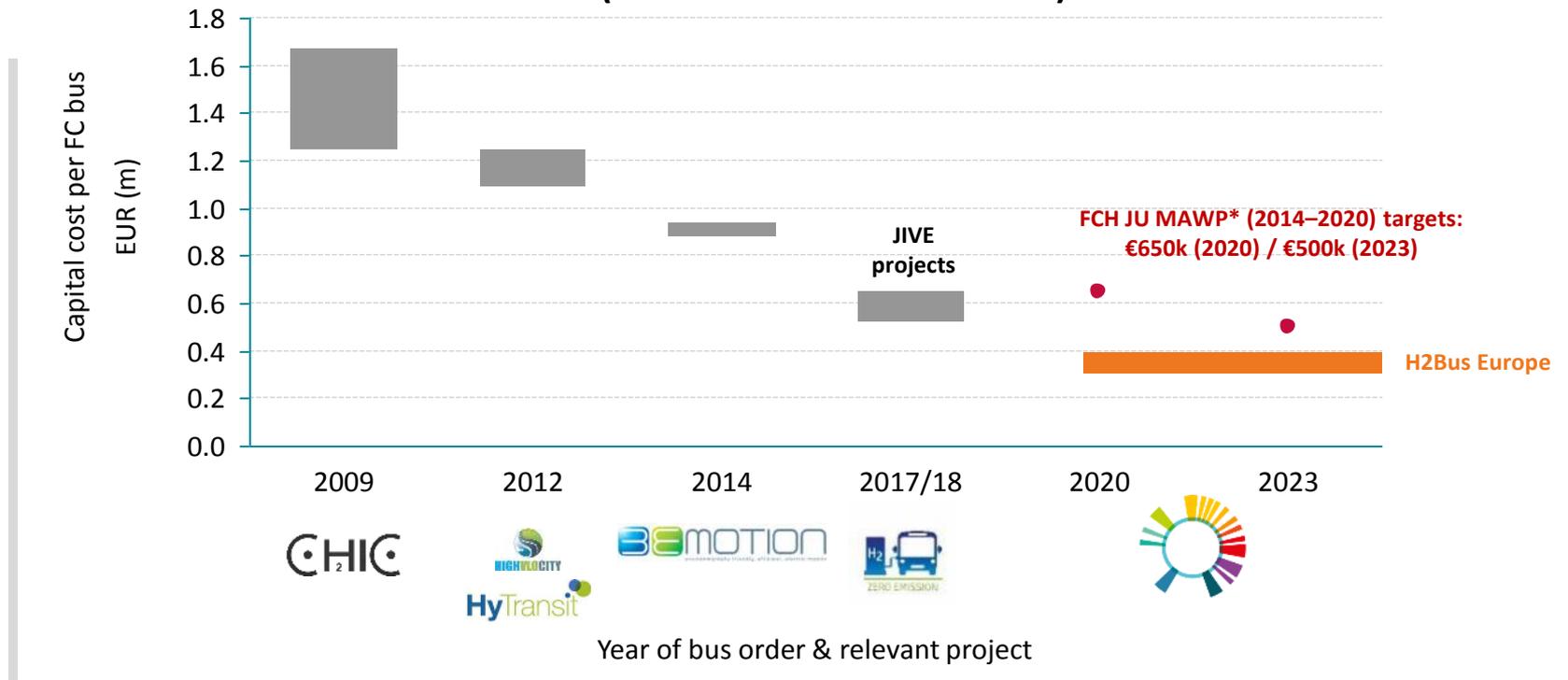


Average bus fleet availability: **88%**

Average fuel cell module availability: **97%**

FCEB Capital Cost Reduction

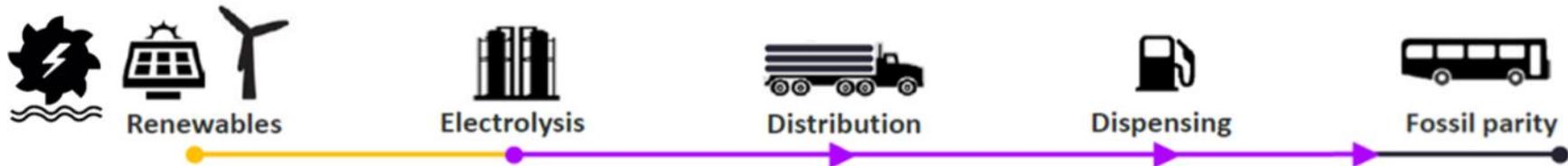
**Capital costs of fuel cell buses ordered in different years
(non-articulated 12m buses)**



* **FCH JU MAWP** is the Fuel Cells and Hydrogen Joint Undertaking’s Multi-Annual Work Plan, the document that sets out the work plan and strategic targets for the second phase of the FCH JU’s programme of research and innovation.

Source: Strategies for joint procurement of fuel cell buses - A study for the Fuel Cells and Hydrogen Joint Undertaking - 2018

Hydrogen Cost Parity



- Centralized hydrogen production facility with **100% renewable and low cost electricity**.
- The electrolytic hydrogen can be transported to several depots via **tube trailers** in a region (150 km radius)
- Hydrogen prices will be in the range €5-7/kg (depending on local electricity prices and volume of demand)
- **Hydrogen will reach parity with diesel** on a per kilometre basis with volume fleet (>100 vehicles)



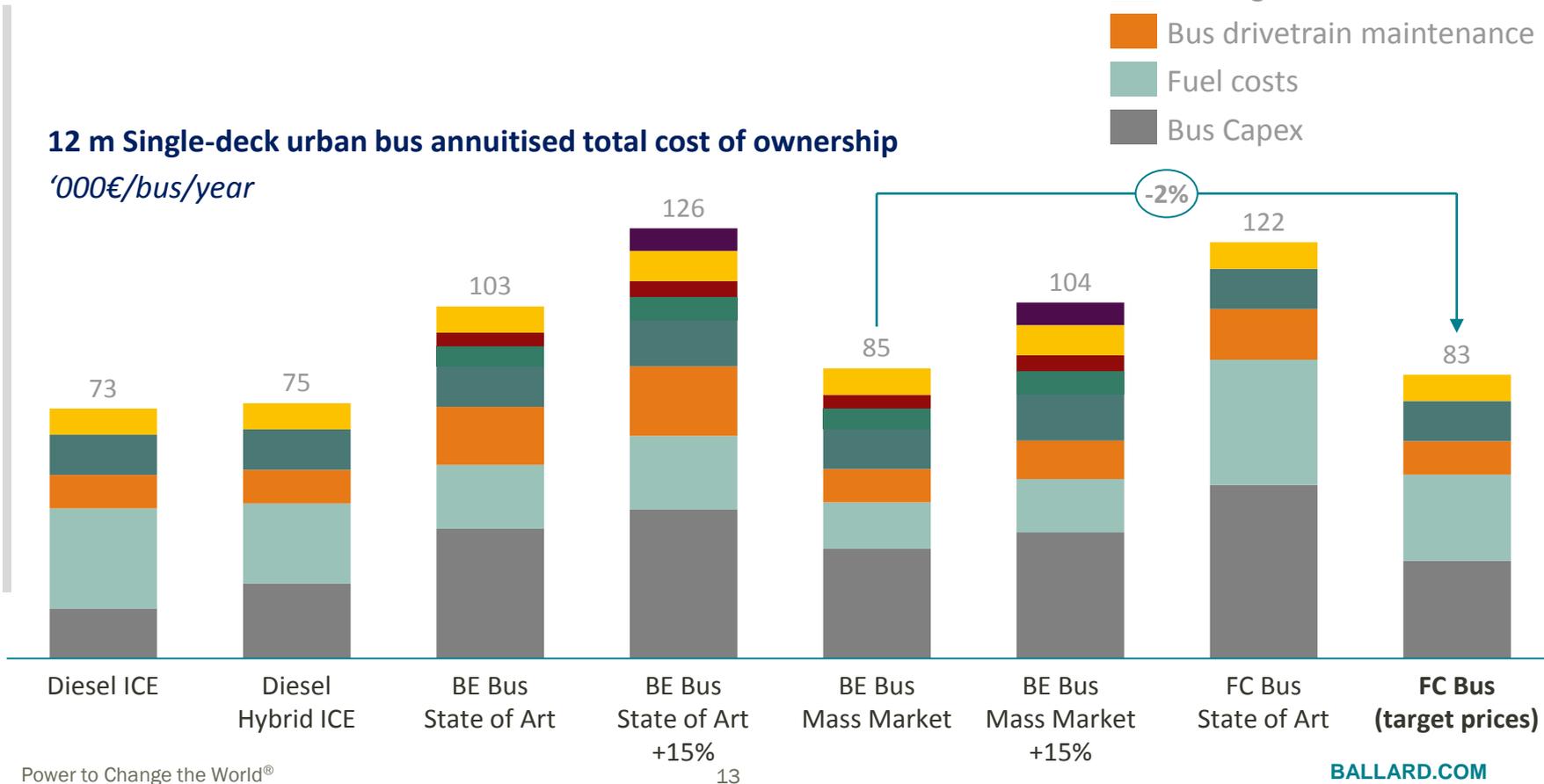
FCEB TCO

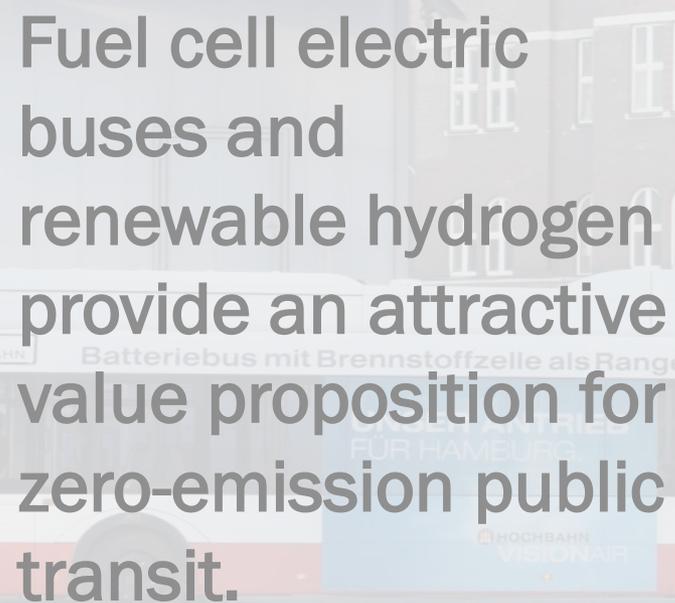
This analysis indicates that, **the fuel cell bus can be the most economical option at scale with green hydrogen**

- Additional bus driver costs
- Depot overhead costs
- Infrastructure Capex
- Infrastructure maintenance
- Bus regular maintenance
- Bus drivetrain maintenance
- Fuel costs
- Bus Capex

12 m Single-deck urban bus annuitised total cost of ownership

'000€/bus/year



The Ballard logo is displayed in white, bold, sans-serif capital letters on a solid blue rectangular background.The text "Wasserstoffstation Hafencity" is written in a black, sans-serif font on a light blue, metallic-looking surface of a building's overhang.A semi-transparent white rectangular box is overlaid on the image, containing the text "Fuel cell electric buses and renewable hydrogen provide an attractive value proposition for zero-emission public transit." The background of the box shows a blurred image of a white and red bus with a fuel cell stack on its side.



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We deliver
fuel cell power
for a sustainable
planet

www.ballard.com