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Fuel cell solutions for sustainable zero emission transit

London case study

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Ballard by the numbers

42
YEARS

900
employees

1,400
patents & applications

26 years Nasdaq
28 years TSX

publicly listed Company

WEICHAI
AngloAmerican
NISSHINBO
大洋电机 BROAD-OCEAN

4
strategic shareholders

1,000+
transit buses

2,200+
trucks

5 TRAIN
projects on track

6 SHIPS
in development

HIGH-POWER DENSITY
stack development program

850 MW
fuel cell products delivered

>6.5million MEAs
produced

>70million
kilometers in operation

>35,000hours
operation of fuel cell stack in London buses

2030
commitment to carbon neutrality

The future of clean transit will be electric

Hydrogen fuel cell buses are electric buses.

Same electric drivetrain as battery electric buses

Battery-fuel cell hybrid configuration

Most OEMs offer common platform for their zero-emission buses

Fuel cell system
generates power onboard the bus

Fuel cell power modules provide 30kW - 100kW of DC power for the transit bus powertrain

Generate electricity from air and hydrogen to recharge batteries and power the electric drive

Ballard has produced over 1,500 power modules for buses and trucks

Hydrogen gas storage
(Typical energy capacity 1250kWh)

Fuel Cell
Solid state DC power generator
Fuel = air and hydrogen

Fuel cell power module

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Fuel cells enhance the performance of electric buses.

>500km Proven range

Significant reduction in vehicle weight
(carry more passengers)

Rapid refueling speeds
(6 to 10 minutes)

1:1 replacement of conventional vehicles

The zero emissions momentum is growing

Regulators are responding:

low emission zones

zero emission vehicle mandates

ban on diesel vehicles

66 countries have announced net-zero emissions as a target by 2050

London FCEB case study

London FCEB deployment projects

- 8 fuel cell buses operated in central London for 10 years(2010-2020) on route RV1 (EU funding)
- Buses are operated by Tower Transit for TfL
- Wrightbus single deck buses powered by Ballard 75kW fuel cell engine and 30kg of H2 storage

Average bus availability: **87%**

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

Fleet has accumulated over

2M km on the road

Up to 18 hours operation per day

>30,000 hrs operation has been demonstrated for fuel cell stack prior to refurbishing

A successful project

Vehicle and fuel cell system operated over 10-year period demonstrating that fuel cells work and last

Bus operator (Tower Transit) service team took ownership of the vehicle and technology and was able to service and maintain the buses.

The project demonstrated the leadership of TfL and The City of London for Clean Transportation and provided great visibility to hydrogen buses with commuters and tourists

What has changed ?

- Vehicle and powertrain were designed in 2009 and technology has evolved since
  - Electric drive train
  - Battery technology
  - Fuel cell technology

- Bus OEMs have now integrated fuel cell electric vehicles as parts of their zero emission electric vehicle platform

- Better offering for hydrogen infrastructure

- Vehicles, maintenance and hydrogen fuel drastic cost reduction

Next

20 new double decker buses built by Wrightbus with Ballard engines will enter service in London in 2021.

Those buses will be powered by green hydrogen produced from North Kent offshore wind farms

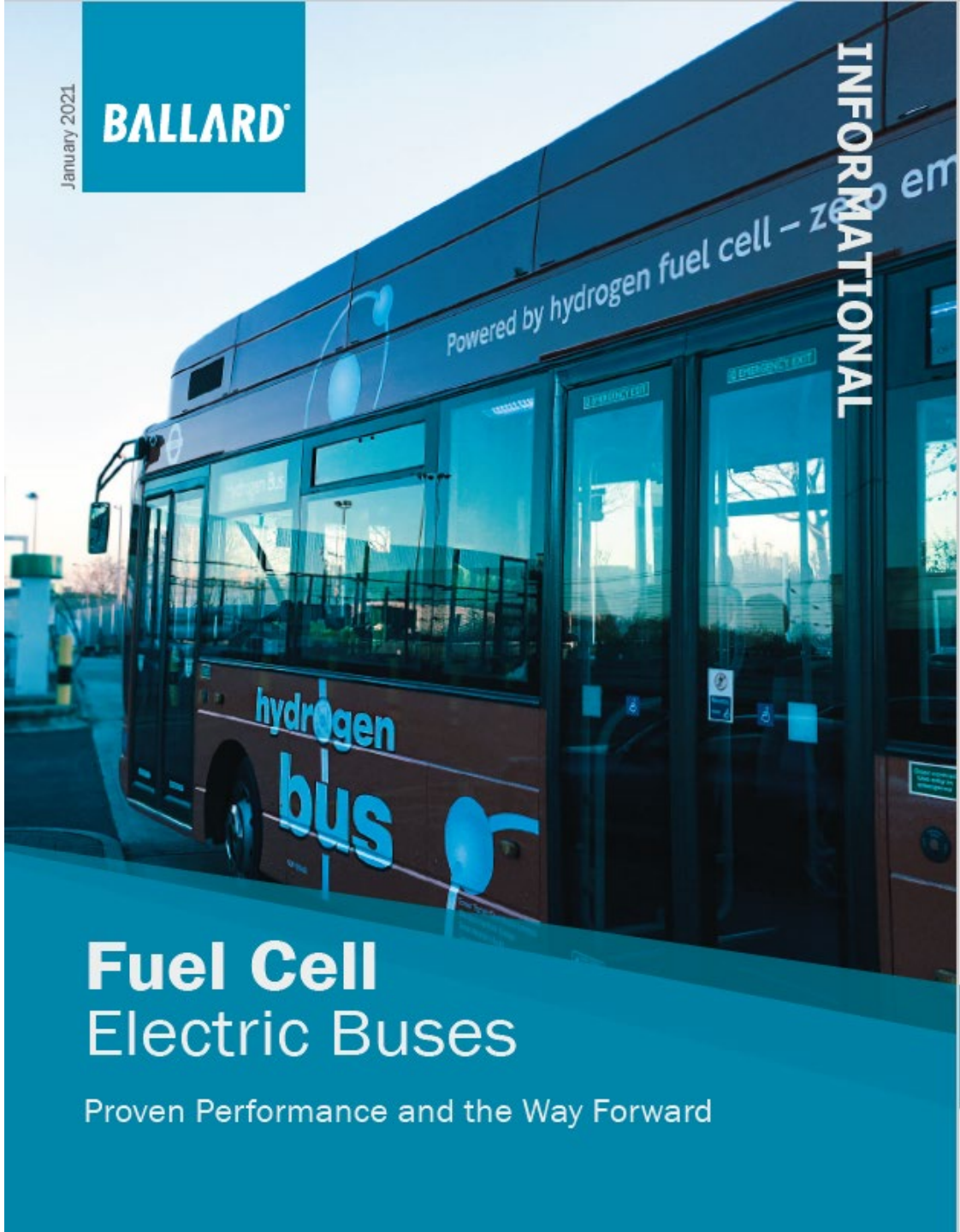
Over 150 fuel cell electric buses will be deployed across other major UK cities including Aberdeen, Birmingham, Belfast, Brighton, Glasgow, Liverpool and London.

Buses
powered by Ballard today

- 1,236 fuel cell buses in service are powered by Ballard
- Multiple bus platforms with OEMs in Europe, US and China
- Over 50 million kilometers in service
- > 30,000 hours fuel cell stack life demonstrated

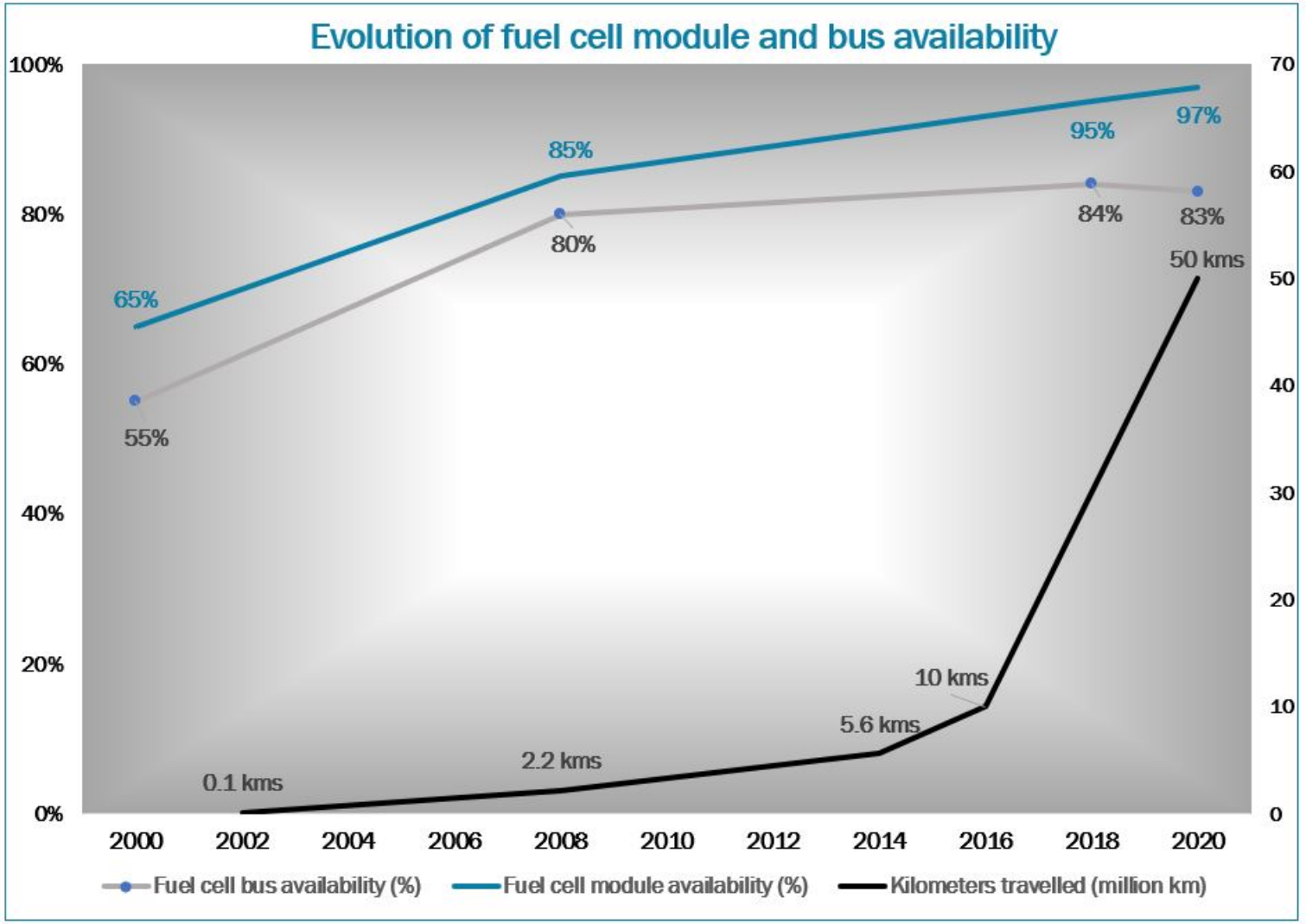
Performance of fuel cell electric buses

- Range: over 500 kilometers
- Fuel consumption: < 8 kilograms/100km
- Fuel cell stack durability: > 30,000 hours (proven in service)
- FCEB current maintenance cost: $0.30/km
- Fuel cell maintenance cost: <$0.10/km
- Fuel cell power systems operates from -40°C to +50°C ambient temperature
- Freeze start from -25°C



Based on fleet of FEB monitored by Ballard in 2018-2020

Performance of fuel cell electric buses



Average bus fleet availability: 83%

Average fuel cell module availability: 97%

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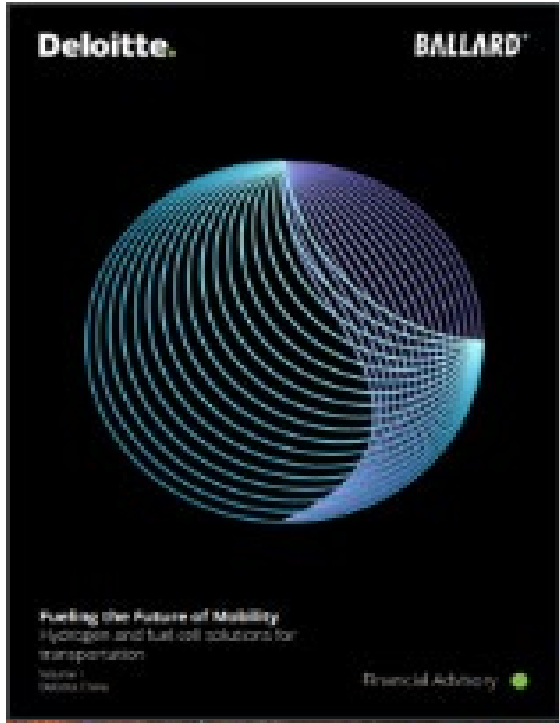
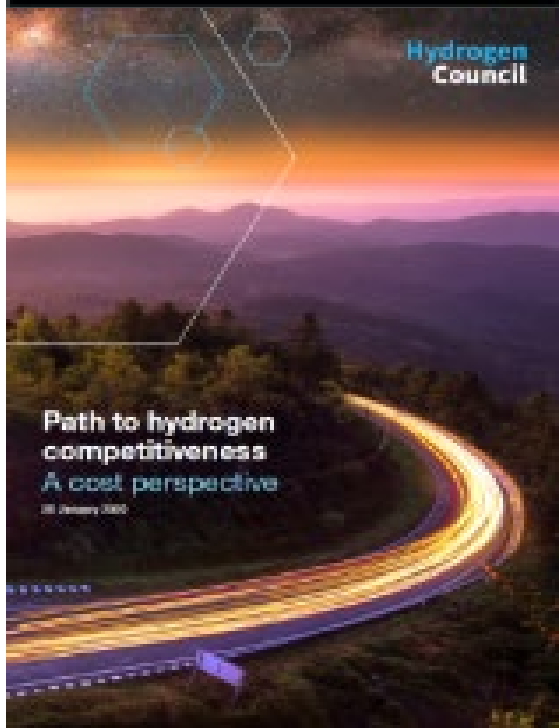
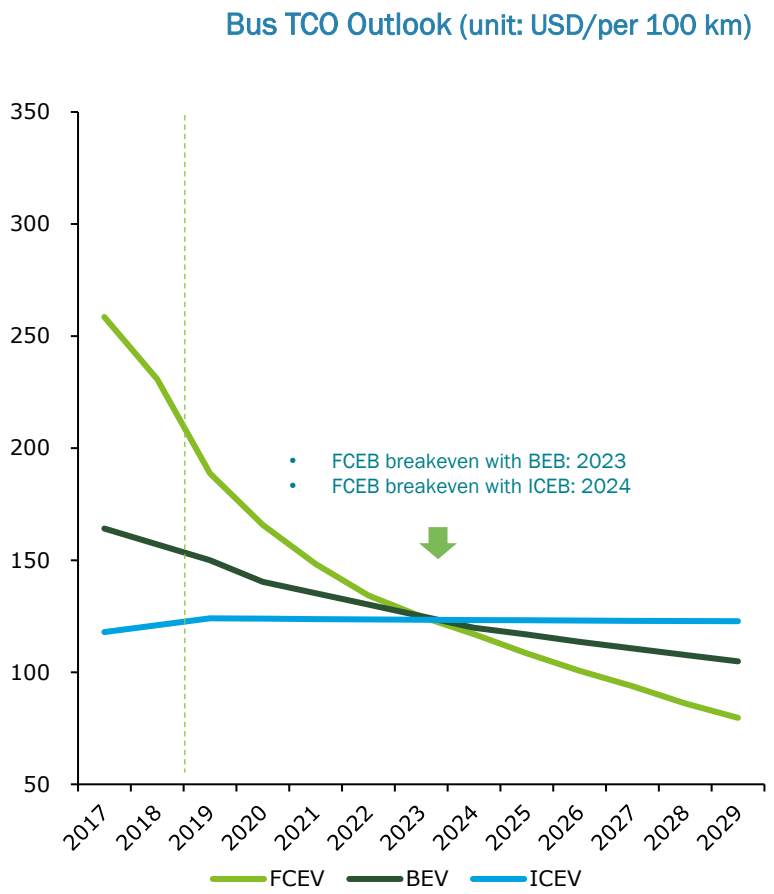
“In less than 10 years, it will become cheaper to run a fuel cell electric vehicle (FCEV) than it is to run a battery electric vehicle (BEV) or an internal combustion engine (ICE) vehicle for certain commercial applications.”

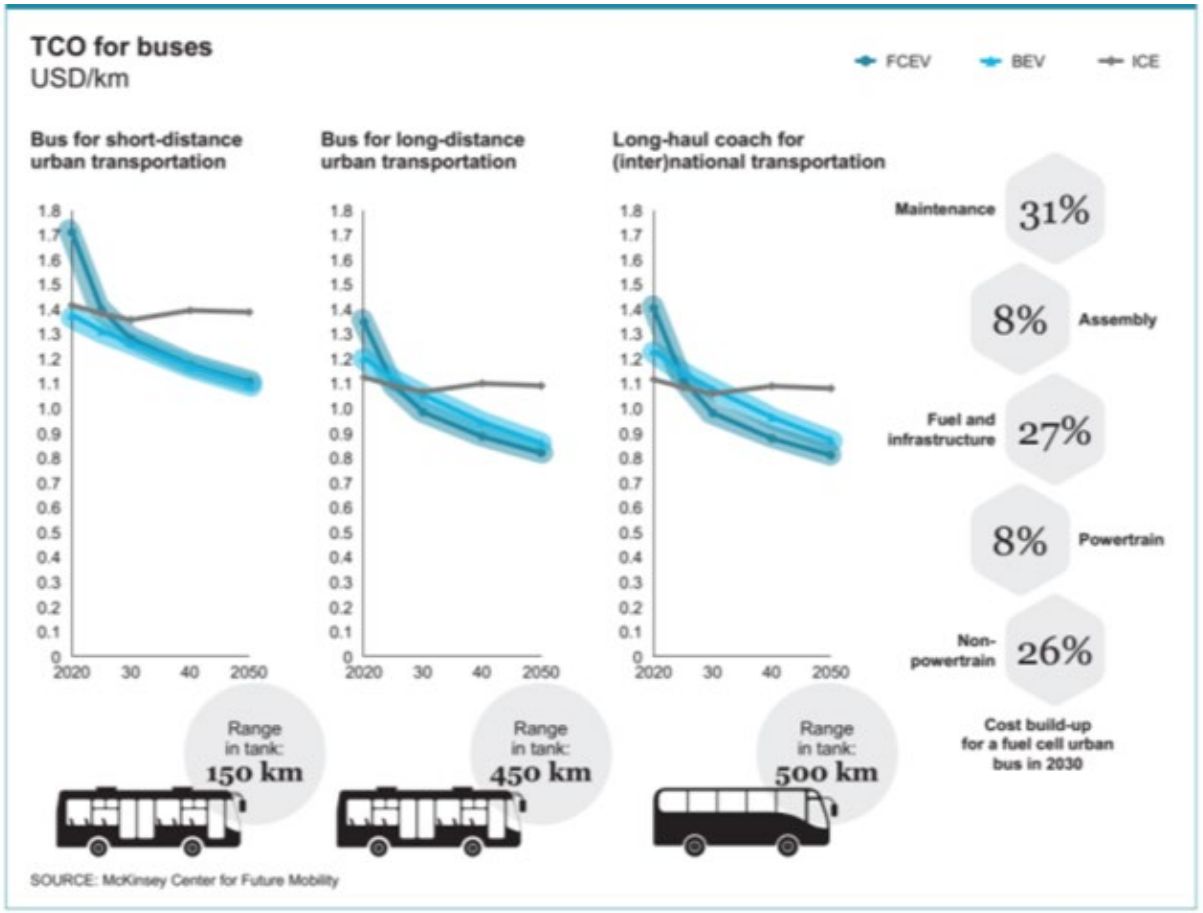
Deloitte-Ballard Report 2020
McKinsey - Path to Hydrogen Competitiveness report 2020





~3-6 Years Away From Economic Viability of FCEBs Without Subsidies





Source: Deloitte-Ballard white paper "Fueling the Future of Mobility: Hydrogen and fuel cell solutions for transportation", January 2020

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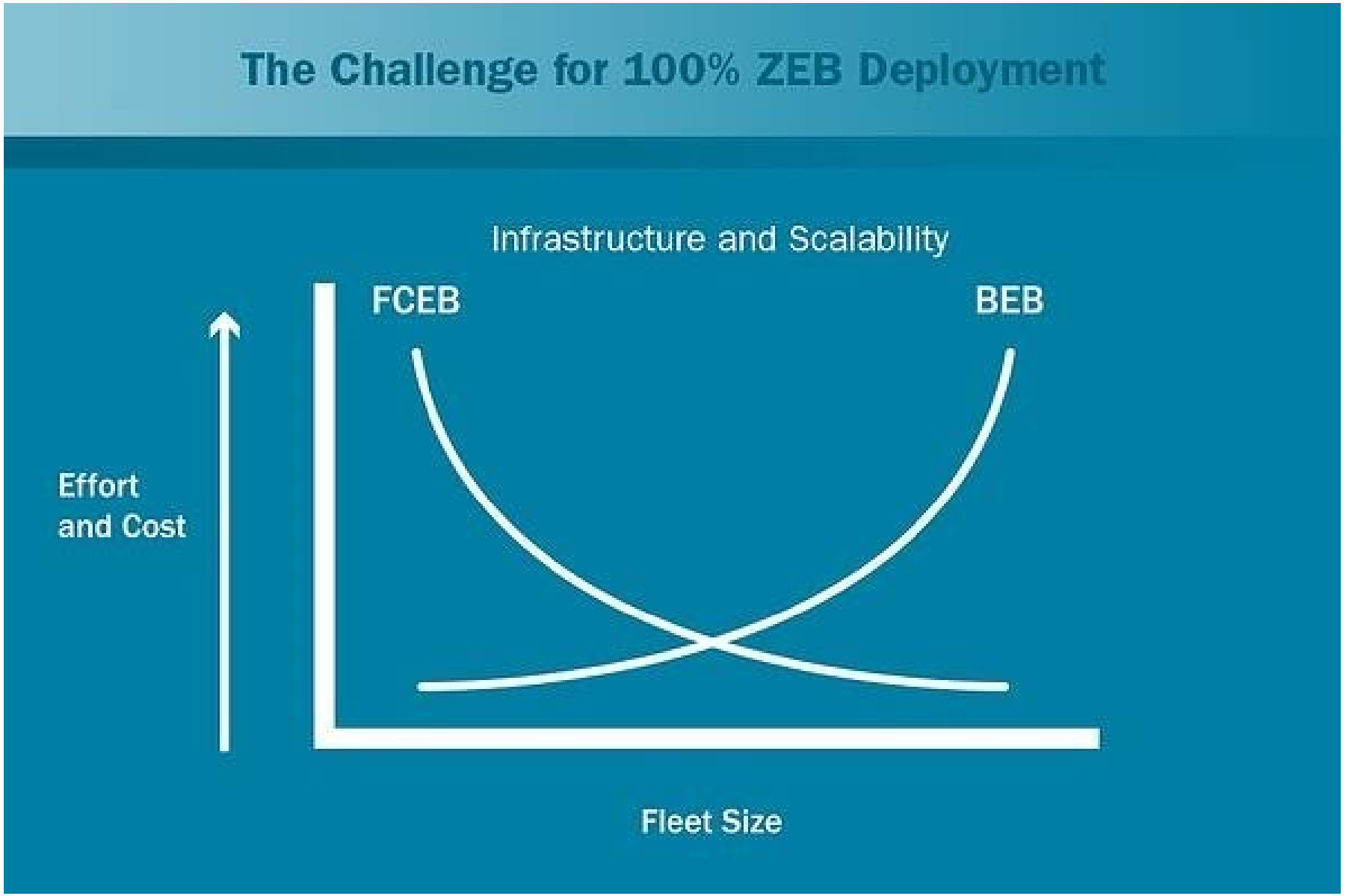


Graph concept courtesy of the Center for Transportation and Environment (CTE)

Hydrogen is a safe and flexible decarbonized fuel

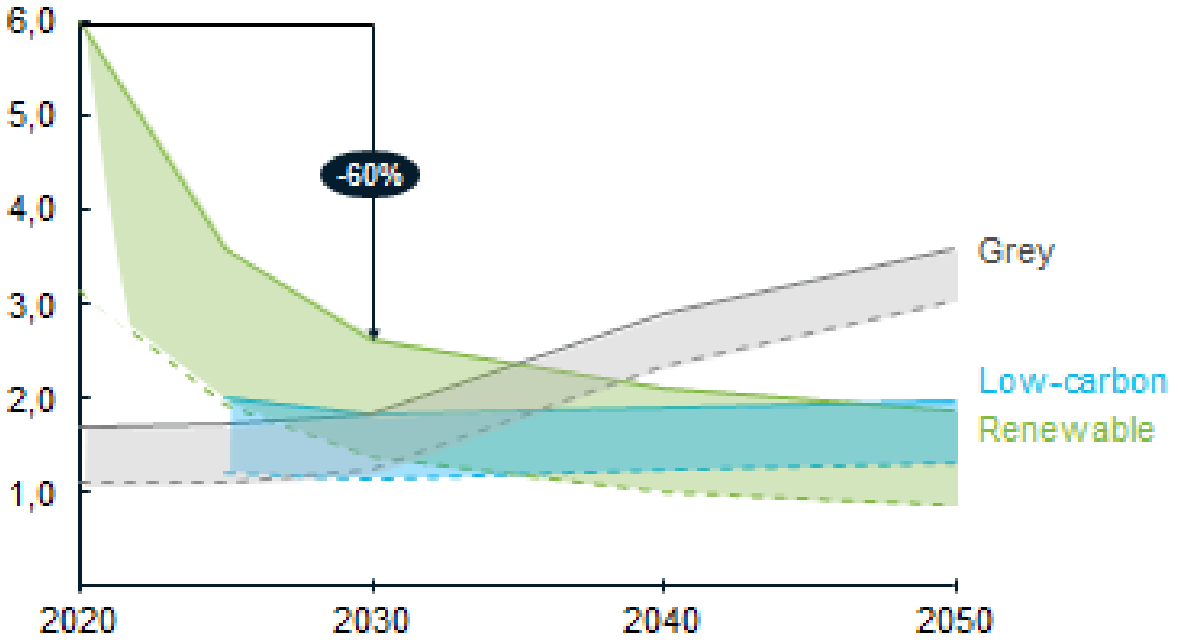
- Safe and manageable
- Supplied as compressed gas or liquid
- Can also be produced on-site
- Competing suppliers offer fixed-price contracts

Excess renewable energy enables production of cheaper green hydrogen in some regions

Renewable hydrogen production costs drop by 60% until 2030

Production cost of hydrogen

USD / kg



McKinsey - Path to Hydrogen Competitiveness report 2020

Drivers of cost reduction

-75%

Capex decline of electrolyzers

-45%

Lower energy costs and higher electrolyzer efficiency

McKinsey & Company 25

So why is hydrogen an attractive fuel for transit?

Hydrogen offers a simple and fixed price per kg (same price at anytime of the day or of the year)
→ easy to budget operation cost

From 2 buses to 100+ buses per depot with incremental CAPEX investment as fleet grows
→ fully scalable

Liquid H2 and compressed H2 delivery options do not require off-site infrastructure investment (power substation, new power lines, recharging infrastructure…)
→ faster deployment

Existing mature supply chain with competitive infrastructure & fuel suppliers
→ drive cost reduction

Fuel service providers are offering turn-key supply contracts including operation & maintenance as well as financing of CAPEX equipment with long term supply agreements → lower risk

As volume of hydrogen demand and production increase, price is expected be less than **$5/kg**
→ further reduction of operating cost

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We deliver fuel cell power for a sustainable planet

Thank you

www.ballard.com