

BALLARD

**FUEL CELL POWERED
ZERO EMISSION**

TRANSPORTATION



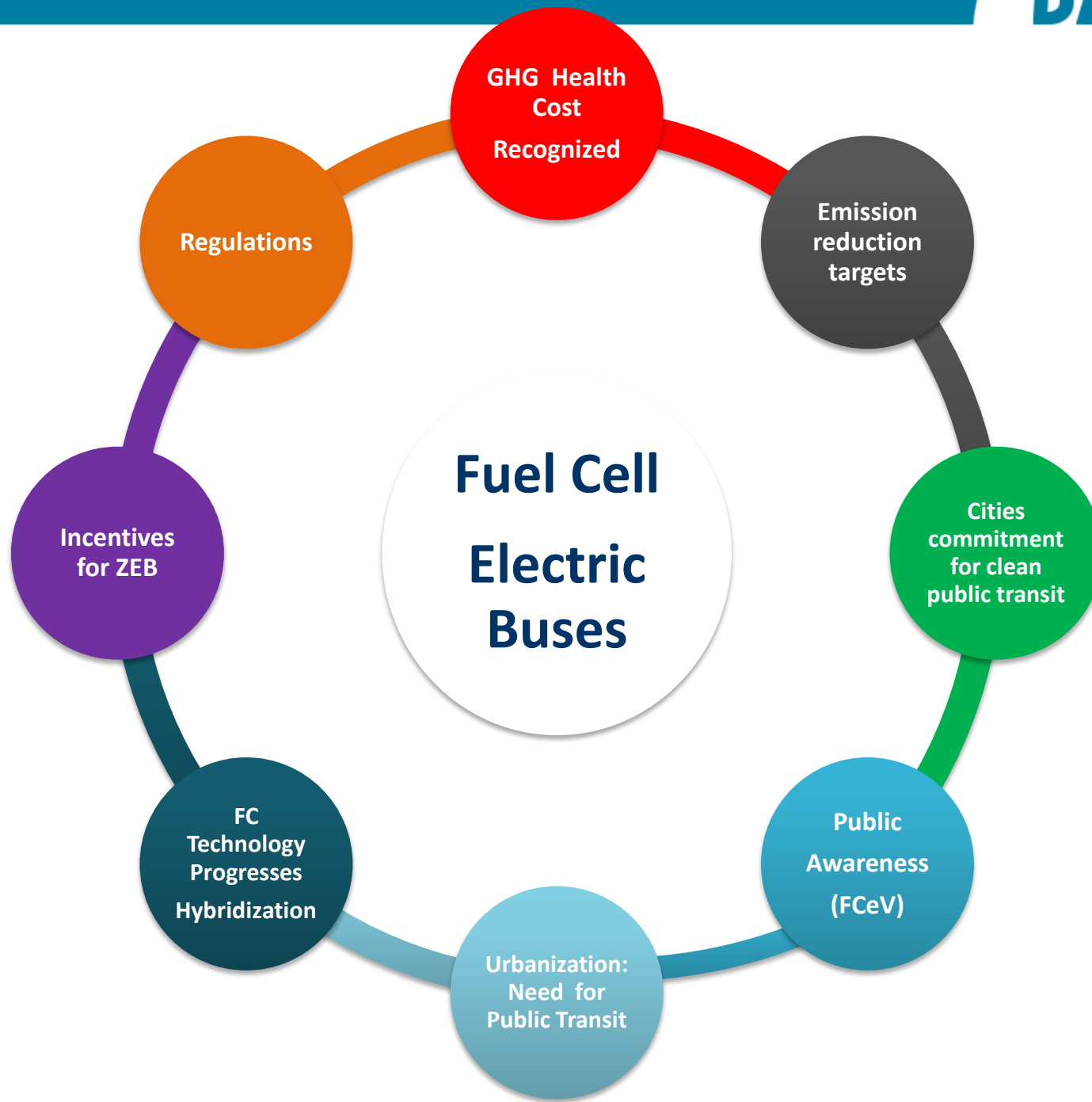
International Partnership
for Hydrogen and Fuel Cells
in the Economy



Integrating Energy Systems for Clean Public Transportation

The Road is Clear for FC buses...

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Why Fuel Cell Buses?

Zero Emissions and Performance

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Fuel cell buses are the most flexible zero emissions option – unlike other electric solutions, they can be operated like diesel buses



High daily ranges

of 300 km on average without refuelling – range extension possible



Full route flexibility

not bound to any required infrastructure on the route



Performance

comparable to diesel buses, e.g. acceleration or gradeability



Fast refuelling

as low as 7 minutes, with several refuelling cycles per day possible



High passenger comfort

due to reduced noise levels and smooth driving experience



Mature technology

with more than ten years and 8M kilometres of operational experience

Performances of Fuel Cell Buses



Table ES-1. Summary of FCEB Performance Compared to DOE/FTA Targets¹

	Units	Current Status ^a (Range)	2016 Target ¹	Ultimate Target ¹
Bus lifetime	years/miles	0.25–4.9/ 7,900–117,000 ^b	12/500,000	12/500,000
Power plant lifetime ^c	hours	660–20,000 ^{b,d,e}	18,000 ✓	25,000
Bus availability	%	40–92	85 ✓	90
Fuel fills ^f	per day	1	1 (<10 min) ✓	1 (<10 min)
Bus cost ^g	\$	2,100,000– 2,400,000	1,000,000 ✗	600,000
Roadcall frequency (bus/fuel cell system)	miles between roadcalls	1,800–6,800/ 9,000–104,000	3,500/ 15,000 ✓	4,000/ 20,000
Operation time	hours per day/days per week	7–21/ 5–7	20/7	20/7
Scheduled and unscheduled maintenance cost ^h	\$/mile	0.54–1.33	0.75 ✓	0.40
Range	miles	240–340 ⁱ	300 ✓	300
Fuel economy	miles per diesel gallon equivalent	5.56–7.71	8 ✓	8

Growing worldwide demand for FC buses

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	Transit bus in service today	Projects in development (bus on the road by 2017)	New projects (bus on the road by 2020)
USA	26	20	28
Europe	62	21	142
China	10	330	> 500

- The number of FC buses deployed in next 12 months will be more than ever built
- Drastic cost reduction for FC buses in past 6 years
- Fuel cell power modules are integrated with batteries in hybrid configurations
- Strong demand from China with “New Energy Vehicle” policy and incentives
- Fuel cell technology is expanding to light rail applications



Challenges to Address

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INTEGRATION / OPTIMIZATION OF COMPONENTS

- Improve vehicle reliability
- Use standard industry components

BUS MANUFACTURING PROCESS

- Common platform for the electric buses / share components parts

MANAGEMENT

- Training of transit agencies maintenance staff

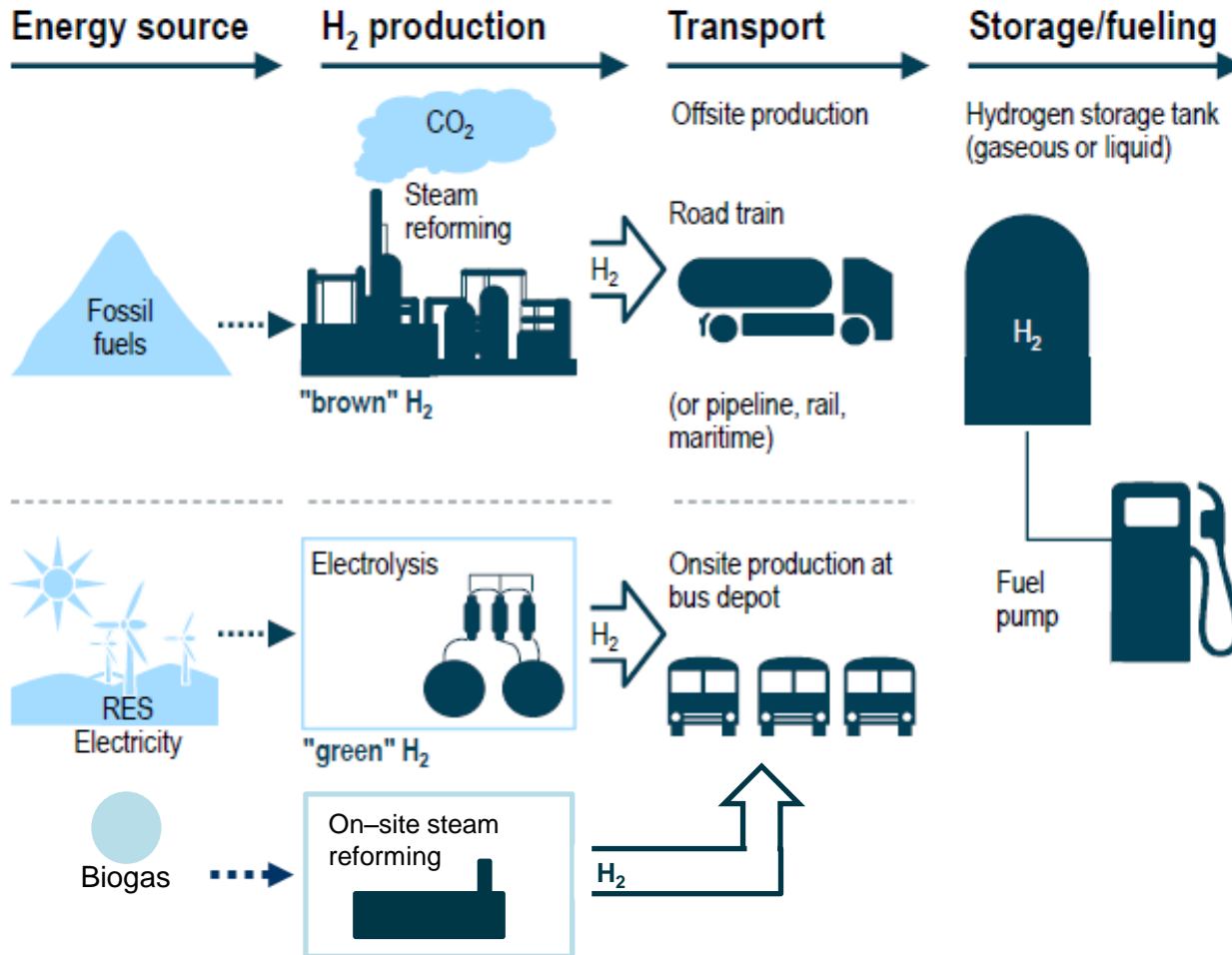
AFFORDABILITY

- Reduce CAPEX of fuel cell buses
 - Increase production volume
 - Leverage fuel cell vehicle supply chain on BOP components
- Better understanding of operating cost over time (life cycle cost)
- Hydrogen supply and cost



Hydrogen Value Chain

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Key elements for successful commercial deployment of FC buses:

- Better/simpler integration of hydrogen supply with FC bus operation
- Stable H2 price (below 5\$/kg to offer attractive fuel economy)
- Access to green/renewable H2 supply for zero emission (Wells-to-wheels)
- Better understanding of options available to transit agencies based on their fleet size and location
 - Compressed gaseous hydrogen in tube trailers
 - Liquid hydrogen delivery and storage
 - On-site steam methane reformation (bio gas)
 - On-site electrolysis (with renewable electricity)
- Sharing of best practices and lesson learned by agencies operating FC buses

Road to success

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3

Integration of hydrogen supply and distribution with transit agency operation

5

Training of maintenance staff

4

Access to (renewable) hydrogen at competitive price

2

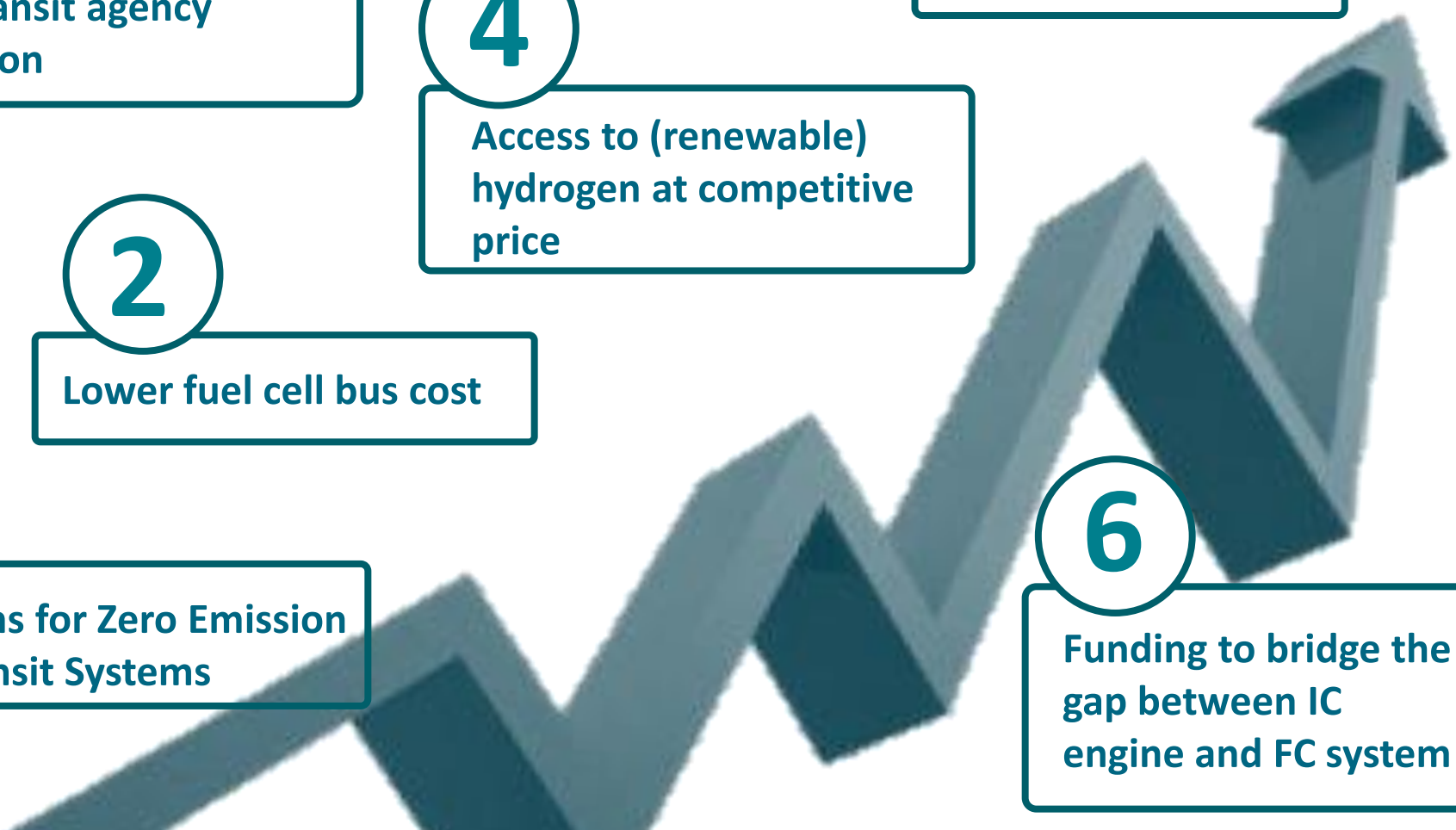
Lower fuel cell bus cost

1

Regulations for Zero Emission Public Transit Systems

6

Funding to bridge the gap between IC engine and FC system



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Thank you

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