

The Ballard logo is displayed in white, uppercase letters on a teal rectangular background. The background of the entire slide is a scenic photograph of a city skyline at dusk, with buildings and sailboats reflected in the water.

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# Zero-Emission Fuel Cell Solutions for Public Transit: Feasibility and Business case

**By: Silvano Pozzi**

Date: June - 2018

# There is a problem...Urban air pollution has major effects on health.

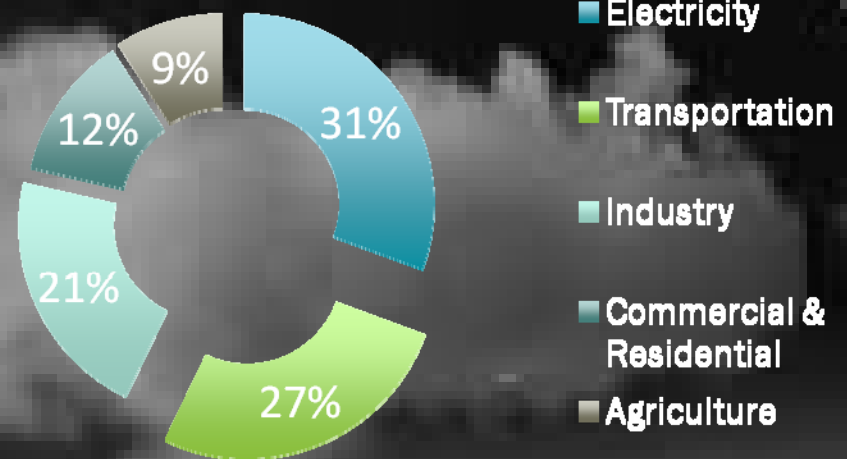
Air pollution costs European economies  
€ 1.5 trillion a year in diseases and deaths.

Air pollution dangerously high for almost half  
of U.S., report finds.

[CBS News](#)

## Where does the pollution come from in the US?

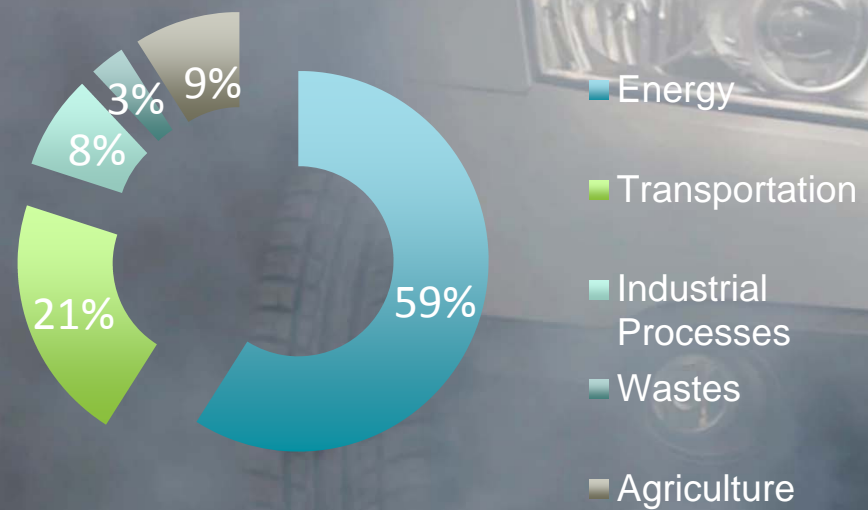
Fossil fuel burning transportation is a major contributor. It is responsible for 27% of greenhouse gas emissions in the US. [US EPA, 2014](#)



**Total US Greenhouse Gas Emissions by Economic Sector in 2014**

## Where does the pollution come from in EU?

Fossil fuel burning transportation is a major contributor. It is responsible for 21% of greenhouse gas emissions.



Total EU Greenhouse Gas Emissions by Economic Sector

**There a quest for solution...There is a political will to make changes.**

- COP21 agreement
- Diesel vehicles are being banned in Europe
- Introduction of low emission zones in cities
- Commitment from transit agencies to move to 100% ZEB by 2025 or 2030





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**There is a target...Clean transit is required to meet emission reduction targets.**

- Public transit takes cars off the road
- Major mover of people in dense urban areas
- Zero-emission public transit is a reality today with electric buses
- Public transit impacts disadvantaged communities



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There is a solution... Fuel cell electric buses provide an operable and affordable zero-emission solution for public transit.

The Ballard logo is displayed in white text on a teal square background in the top left corner of the slide.

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## Zero-emission electric buses are a reality.

- Electric powertrains are mature
- Growing worldwide commercial deployments
- Efficient drive
- Benefited from progress in battery technology
- Low noise and passenger comfort



The Ballard logo is a teal square with the word "BALLARD" in white, sans-serif, uppercase letters. A registered trademark symbol (®) is located to the upper right of the word.

## Hydrogen fuel cell buses are electric buses integrate-able to any existing infrastructure.

- Same electric drivetrain as battery electric buses
- Battery-fuel cell hybrid configuration
- Fuel cell module is on-board battery charger
- Most OEMs offer common platform for their zero-emission buses



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## Fuel cells enhance the performance of electric buses.

- Longer range (400 km plus)
- No compromise on passenger load
- Fast refilling (less than 10 min)
- Recyclable
- Improve vehicle efficiency by using heat from the fuel cells





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Wasserstoffstation HafenCity

# Fuel cells enhance the performance of electric buses.

- Improve vehicle efficiency and battery lifetime

## Transit buses should transport passengers.

- Passengers represent 1/3<sup>rd</sup> of bus gross weight
- Longer range can be achieved with more batteries (up to 650kWh of batteries for 450km)
- But it increases bus weight up to 2,000kg
- Fuel cell buses are lighter and can provide a longer range with a full passenger load



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Fuel cell electric buses can replace diesel buses without significant changes to operational requirements.

- No need to adapt routes and schedule
- Better asset management
- No roadside infrastructure
- 1:1 replacement of conventional buses



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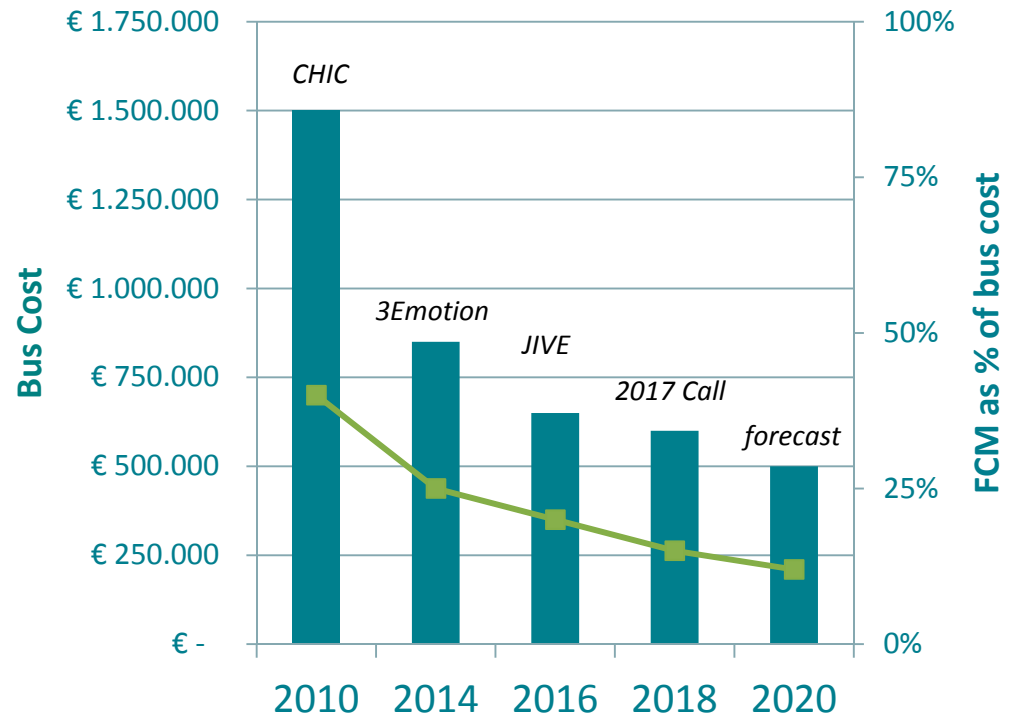
## Fuel cell electric buses are affordable.

- Bus cost has dropped by 100% since 2010
- Funding and incentives are available to bridge price gap with conventional buses
- Higher fuel economy than conventional buses
- Attractive operating cost

## EU Case - Fuel cell electric bus cost reduction driven by:

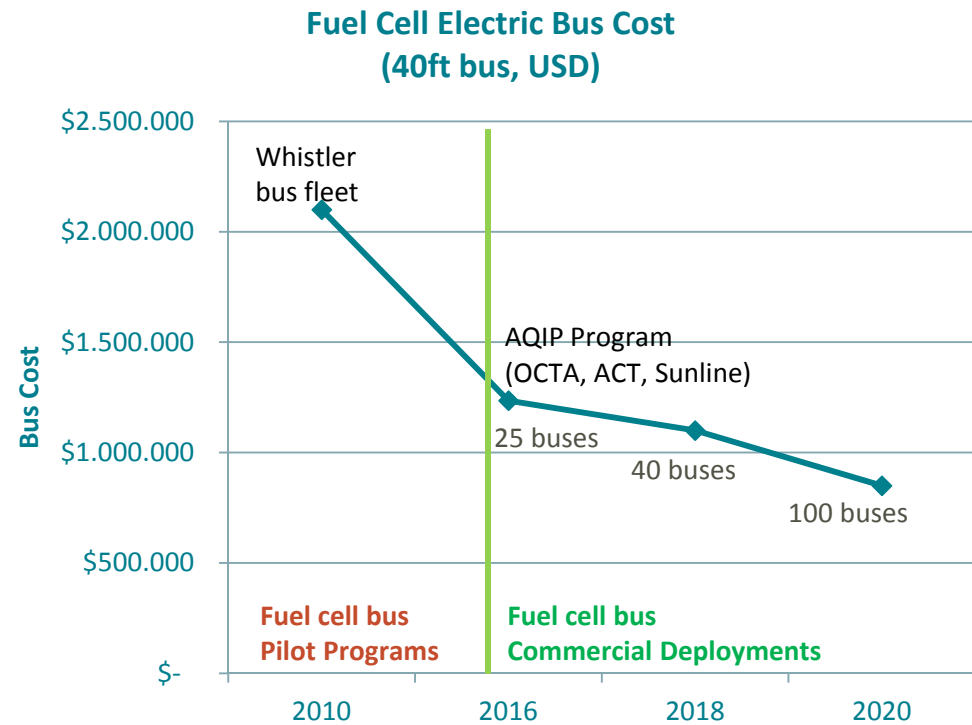
- Optimization of electric bus platform
- Hybridization of fuel cell with battery
- Reduction of fuel cell module size from >200kW to less than 100kW
- Integration and fuel cell system cost reduction with volume production

### Fuel Cell Electric Bus Cost (12 m bus in Euro)



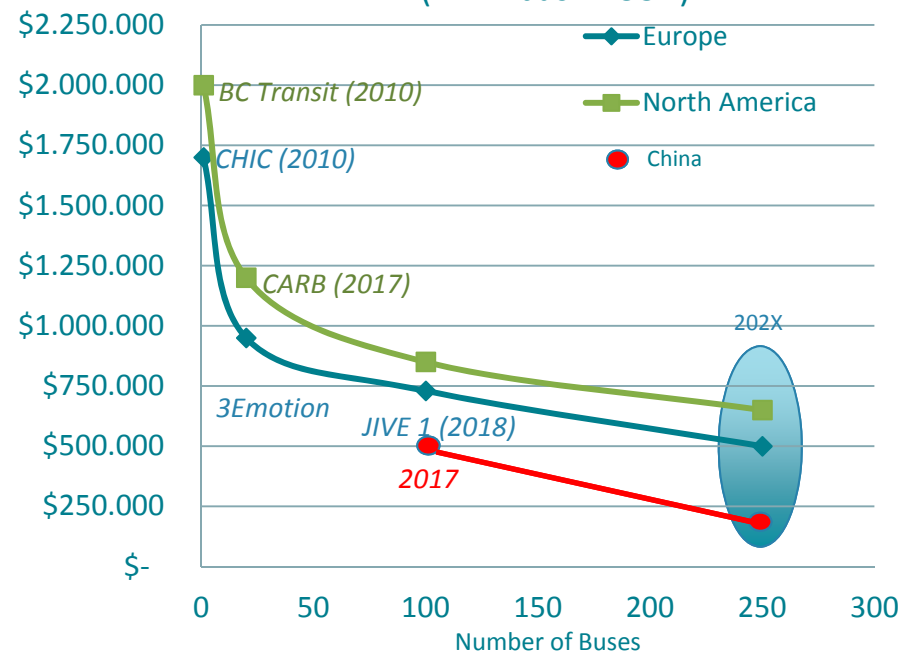
## US Case - Fuel cell electric bus cost reduction driven by:

- Optimization of electric bus platform
- Hybridization of fuel cell with battery
- Reduction of fuel cell module size from >200kW to less than 100kW
- Integration and fuel cell system cost reduction with volume production
- FCEB will be within \$50k of BEB by 2020+



**China Case -  
Major gains  
being achieved  
even with  
modest scaling.**

**Fuel Cell Electric Bus Cost**  
(12 m bus in USD)



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**Driving volume  
by  
simultaneously  
creating demand  
for trucks and  
buses.**



## Starting a new energy revolution.

- Bus demand stimulates hydrogen production projects
- Hydrogen allows a different route to get low carbon energy into our cities
- Hydrogen can solve problems of energy supply and grid instability
- Hydrogen fuel cell bus deployments open the road for trucks and rail applications

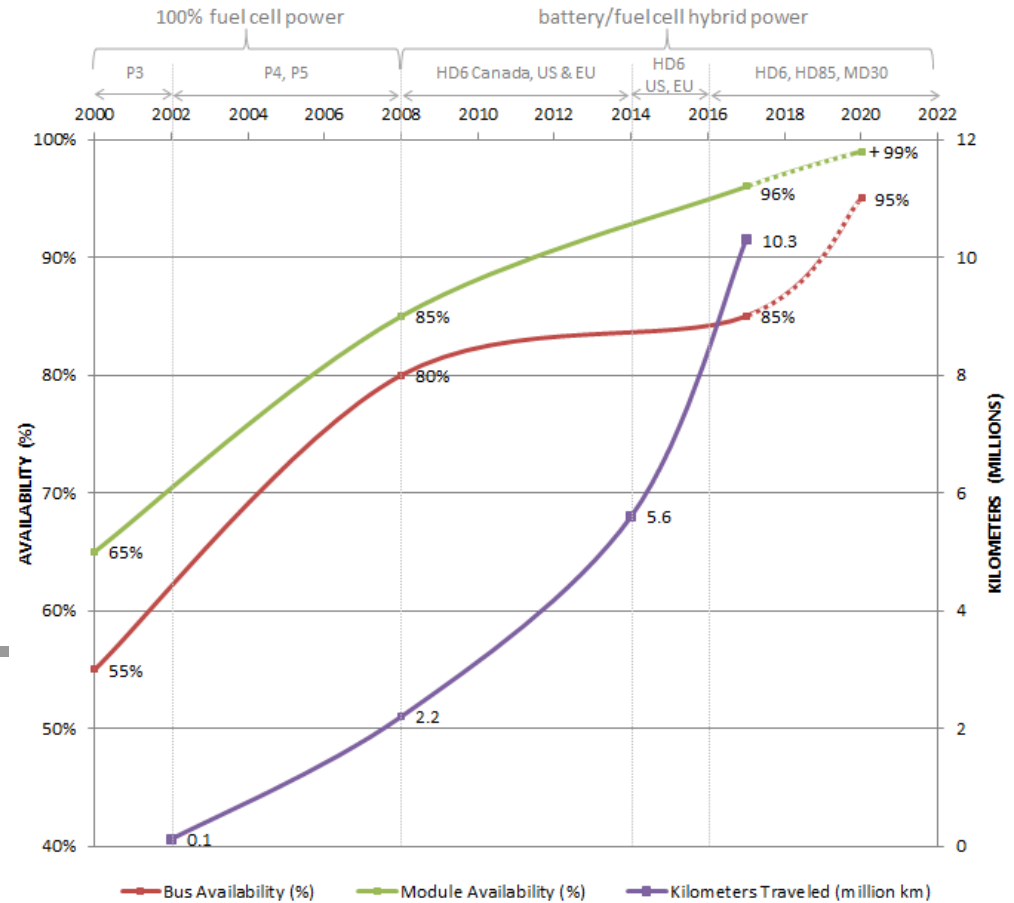


## Hydrogen provides scalability for large bus depots.

- Hydrogen infrastructure is fully scalable
- 1 bus = 30 kg of H<sub>2</sub> per day
- 20 buses = 600kg/day
- 75 bus station with 2x 4.5t storage of liquid H<sub>2</sub> will have a footprint of 400m<sup>2</sup> (4,300ft<sup>2</sup>)



Years of road experience with performance equivalent to conventional buses.





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## Product Flexibility and Scalability FCveloCity® fuel cell module for heavy- duty vehicles

- Zero-emission solid state power module
- Flexible platform from 30kW to 200kW
- Safe (built-in safety features)
- Quality tested
- Durable (25,000hrs stack life in service)
- Fuel efficient



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Committed to sustainable mobility,  
and clean air for everyone.