

BALLARD

Opportunity for Hydrogen and Fuel Cells in the Decarbonisation of Transportation

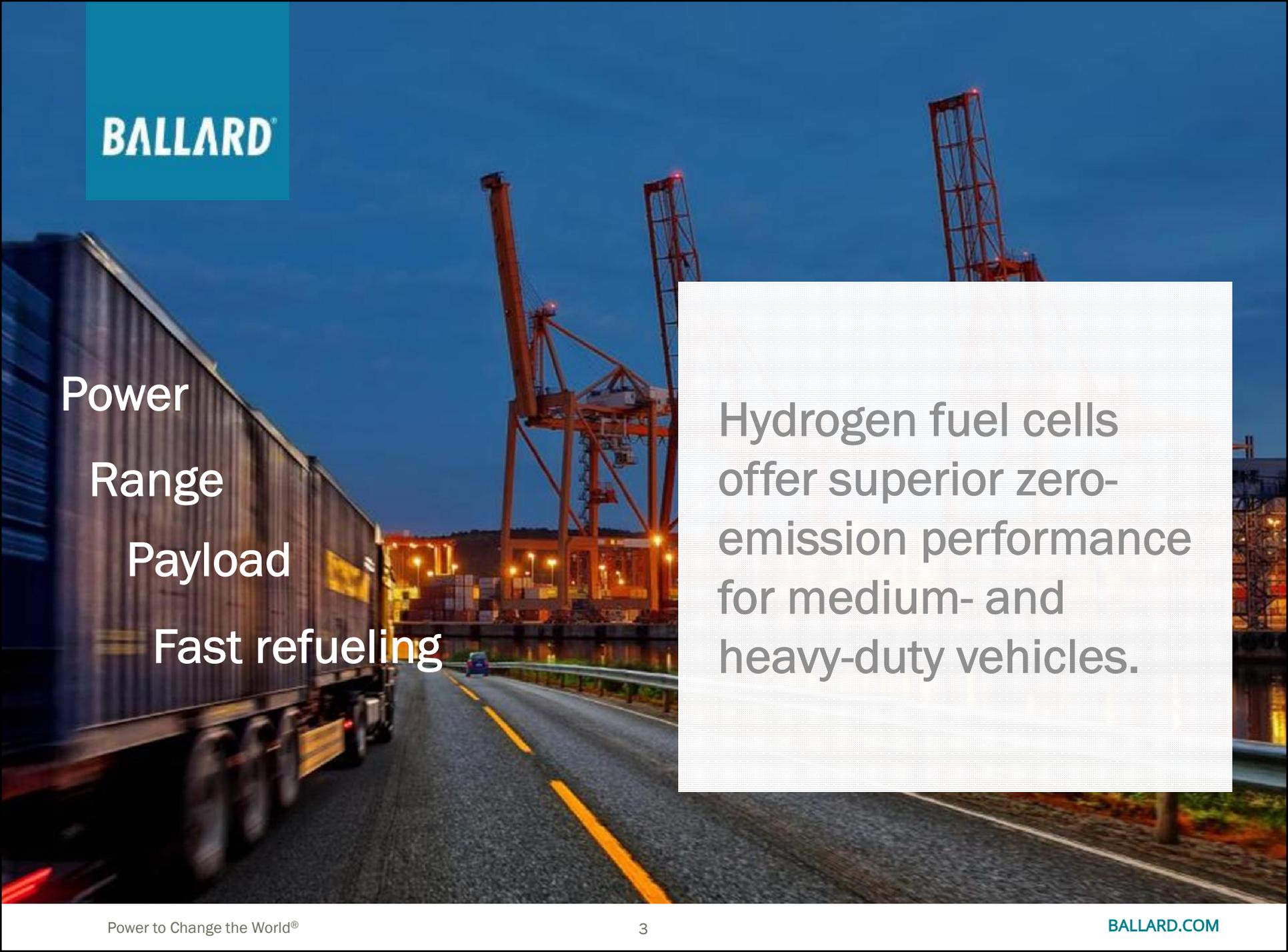
TJ Lawy
Principal Engineer

March 2020



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Transport responsible for 24% of Canada's GHG emissions and its emissions are increasing at a faster rate than any other sector.

The background image shows a large semi-truck with a dark container trailer driving on a road at night. In the background, there are port cranes and industrial structures illuminated by lights. The Ballard logo is in the top left corner.

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Power

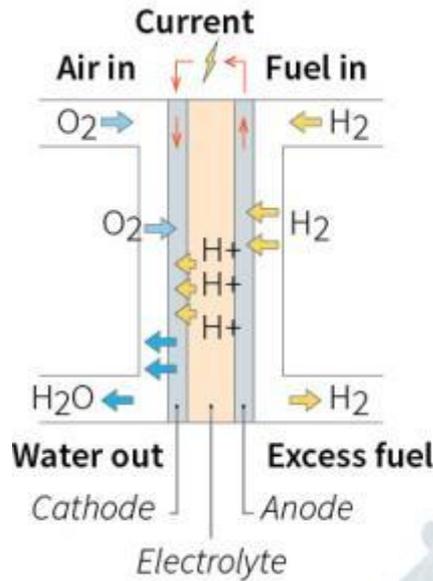
Range

Payload

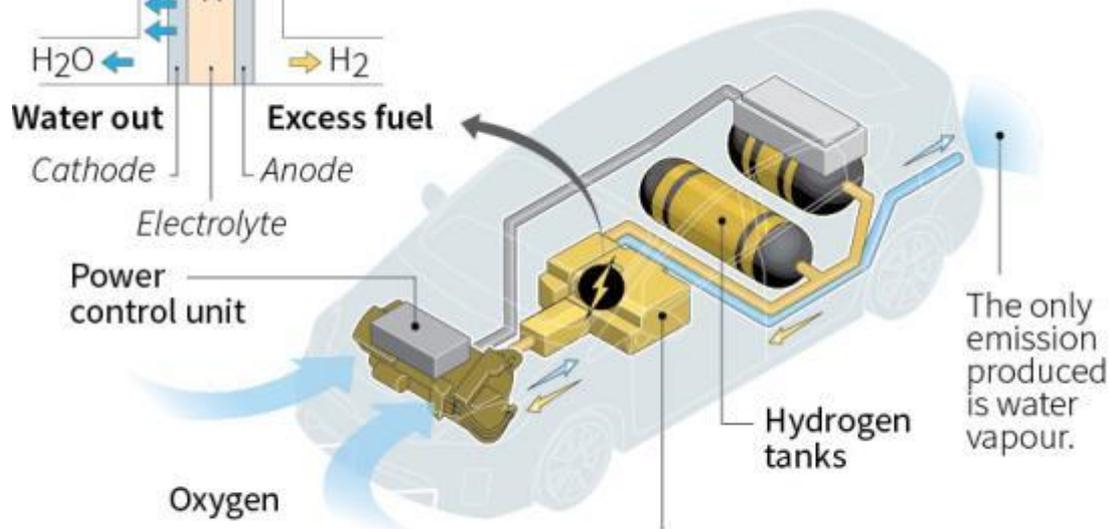
Fast refueling

Hydrogen fuel cells offer superior zero-emission performance for medium- and heavy-duty vehicles.

How a PEM Fuel Cell Works



How they work: Oxygen from the air combines with hydrogen in the fuel cell creating a chemical reaction that produces power for the electric motor.



Fuel cell - Requires a continuous supply of fuel and oxygen to sustain the reaction.

Source: Reuters

Fuel Cell Electric Buses

- Have been deployed for decades in revenue service
- Match diesel performance: any route, any time
- Refueling infrastructure is scalable to transform entire fleet to zero-emission
- Cost competitive with other electric solutions and simpler to integrate into existing transit operations.



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- More than 2,000 fuel cell buses in operation worldwide, 570+ powered by Ballard.
- Ballard-powered vehicles have travelled 30 million kilometers – *enough to circle the globe 750 times*
- >35,000 hours of bus operation
~8 years with no stack replacement



Hydrogen is a fuel similar to CNG with no carbon

- Safe and manageable
- Supplied as compressed gas or liquid
- Station is scalable to fuel 100s of buses
- Competing suppliers offer fixed-price contracts
- Provides resiliency during an emergency



Fuel cell powered marine vessels

- IMO is setting mandates to reduce GHG emissions from ships
- Fuel cells provide long range, quick refueling and flexible integration
- Ballard fuel cells will power ferries, barges and auxiliary loads for cruise ships

Centralized hydrogen infrastructure at ports can fuel many applications

- Vessels
- Onshore power
- Cargo handling equipment
- Drayage trucks

Benefits of developing hydrogen economy

- Decarbonization of hard-to-abate sectors
- Economic growth and job creation through the development hydrogen supply chain and infrastructure
- Leverage Nova Scotia's wind resources to transition away from coal

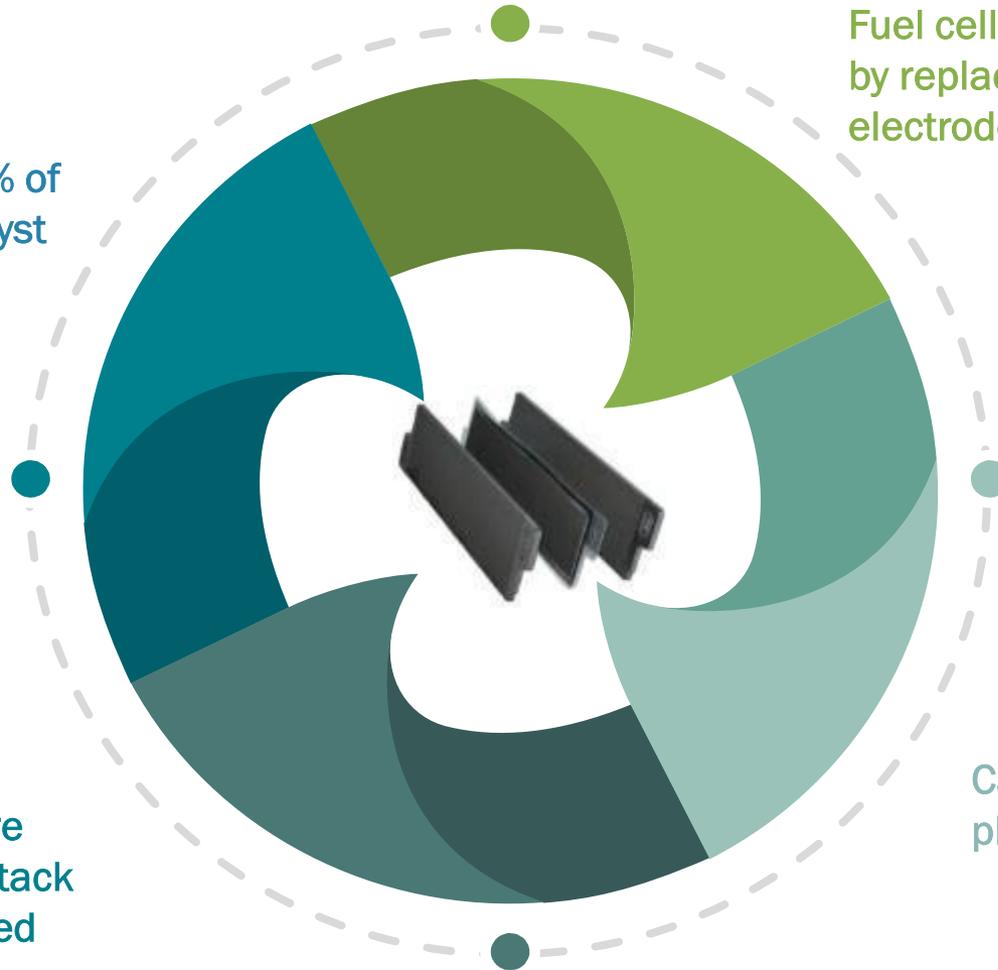
Fuel cells are the most sustainable zero-emission solution

More than 95% of platinum catalyst is recycled

Fuel cell membranes are recycled and stack is re-conditioned

Fuel cell stacks are refurbished by replacing the membrane electrode assembly (MEA)

Carbon bipolar plates are re-used



Recommendations for enabling hydrogen and fuel cells in Halifax

- Implement aggressive GHG reduction goals for the city and port
- Commit to procuring only zero-emission vehicles for government and city-owned fleets
- Ensure zero-emission technology neutrality in regulations and public tenders
- Commission a study to evaluate the business case for the deployment of hydrogen fuel cell applications

BALLARD BY THE NUMBERS

40
YEARS
1979-2019



900
employees



1,400
patents & applications

25 years  Nasdaq

27 years 

publicly listed Company

WEICHAI



NISSHINBO



4
strategic shareholders



570+
transit buses



2,000+
trucks delivering goods



4 TRAIN
projects on track



5 SHIPS
in development



12,000
forklifts in operation



\$80 million
automobile stack
development program



670 MW
of fuel cell products
delivered



>5.5million MEAs
produced



>30million
kilometers of vehicle
experience



>30,000hours
operation of fuel cell
stack in London buses

At Ballard,

**We deliver fuel cell
power for a
sustainable planet.**



Online References

Links for further reading

IEA Report: The Future of Hydrogen

- **The time is right** to tap into hydrogen's potential to play a key role in a clean, secure and affordable energy future.
- Hydrogen can help tackle various **critical energy challenges**.
- Hydrogen is versatile.
- **Hydrogen can enable renewables** to provide an even greater contribution
- There have been false starts for hydrogen in the past; this time could be different.
- Hydrogen can be used much more widely
- However, **clean, widespread use of hydrogen in global energy transitions faces several challenges**



www.iea.org/reports/the-future-of-hydrogen

Learn more about FCEBs zeroemissionbus.org

Maintenance

The facts on maintenance and support

Fuel Cell

What is a fuel cell?

Value

The value proposition of fuel cell buses

Fuel Cell Electric Bus

Integration

Fuel cell integration in the bus platform

Proven Technology

A proven zero-emission solution

Hydrogen

Hydrogen and infrastructure

Click a category to explore

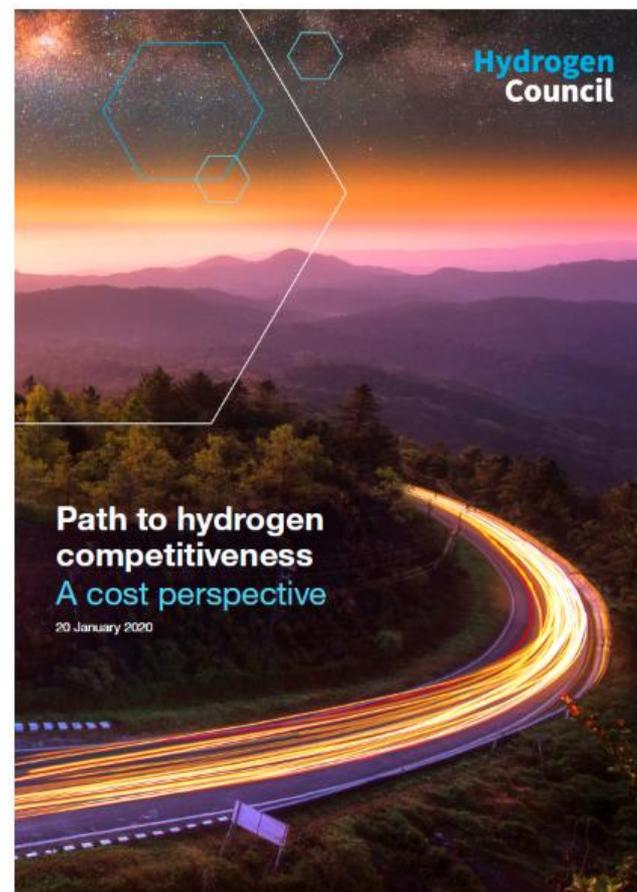
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Path to Hydrogen Competitiveness

- The cost of hydrogen solutions will fall sharply within the next decade – and **sooner than previously expected**
- Cost is projected to decrease by **up to 50% by 2030** for a wide range of applications
- Cost drivers:
 1. Strong fall in the cost of producing low carbon and renewable hydrogen;
 2. Lower distribution and refuelling costs thanks to higher load utilisation and scale effect on infrastructure utilisation; and
 3. Dramatic drop in the cost of components for end-use equipment under scaling up of manufacturing.



hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/

Fueling the Future of Mobility

- In less than 10 years, it will become cheaper to run a FCEV than it is to run a BEV or an ICE vehicle for certain commercial applications
- Total Cost of Ownership (TCO) for commercial hydrogen vehicles will fall by more than 50% in the next 10 years
- The cost of running commercial FCEVs will decline as fuel cell system and hydrogen costs decrease by about 70% and 63%

info.ballard.com/deloitte-vol-1-fueling-the-future-of-mobility

