BALLARD

Fuel Cell Catalysts for Zero Emission Heavy Duty Applications

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Charles Hatchett Award Webinar
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Outline

Powering the Future with Hydrogen

An introduction to Ballard and the need for hydrogen for global to decarbonization

Fuel Cell Buses and Trucks

Value proposition for fuel cells in these applications

Fuel Cell Catalyst Requirements

How improved catalysts will translate to more durable and lower cost fuel cells

Ballard By The Numbers

40+ YEARS

900 employees

1,400 patents & applications

25 years Nasdaq

27 years TSX

publicly listed Company

WEICHAI
AngloAmerican
NISSHINBO
大洋电机 BROAD-OCEAN

4 strategic shareholders

1,000+ transit buses

2,200+ trucks

4 TRAIN projects on track

6 SHIPS in development

12,000 forklifts in operation

HIGH-POWER DENSITY stack development program

670 MW fuel cell products delivered

>5.5million MEAs produced

>50million kilometers in operation

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

Global operations: Our markets and solutions today

Clean Mobility






- Heavy Duty Vehicles and Rail
- Marine vessels
- Material Handling
- Light Duty vehicles

Stationary Systems


- Distributed Generation
- Backup Power

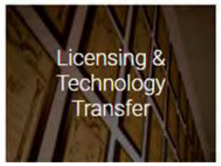
Power Products

- Heavy duty fuel cell power modules
- Fuel cell stacks
- Fuel cell power systems





Technology Solutions

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Powering the Future
with Hydrogen

Global decarbonization is putting the focus on hydrogen

The fight against climate change and air pollution is driving the demand for fuel cell technology that converts hydrogen in clean electricity

Hydrogen is a flexible energy carrier and fuel:

in cars, trucks, buses, trains and ships

in industry and for critical infrastructure

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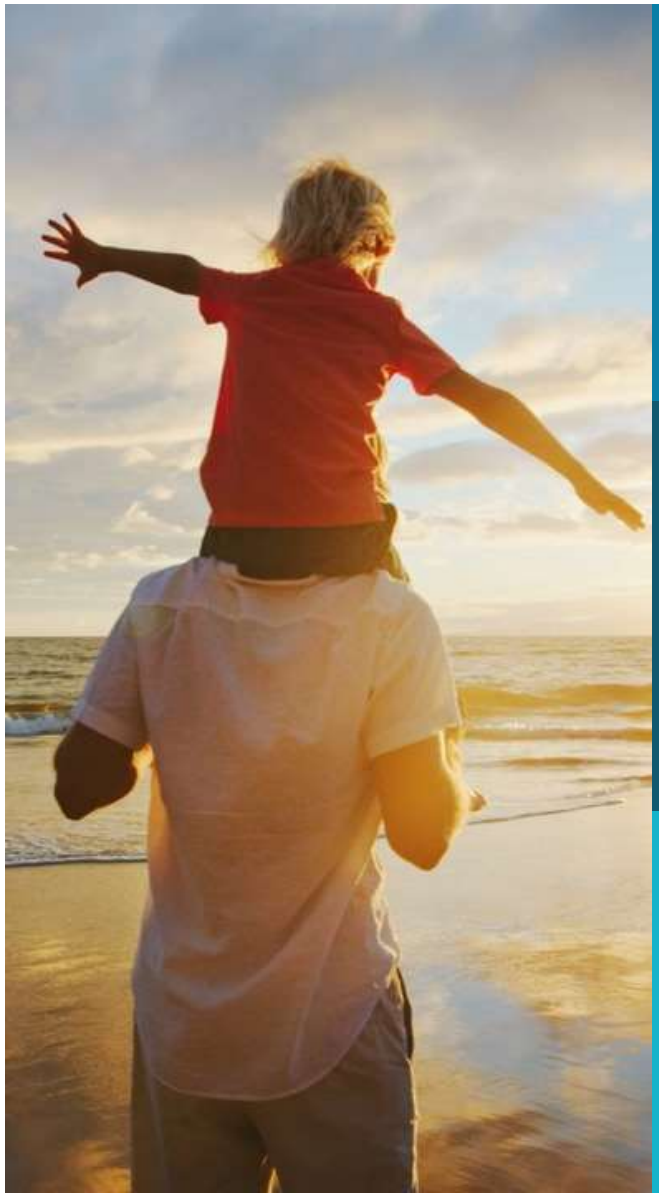
Hydrogen is key to the decarbonization of our economy

Hydrogen can decarbonize sectors that are difficult to abate. Governments are recognizing it.



18 countries

have developed hydrogen roadmaps

70%

these countries account for 70% of global GDP

92 members

the Hydrogen Council formed in 2017 has now 92 members

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Today there are already 30,000 fuel cell vehicles on the road.

Hydrogen Council Vision for 2030

Our industry will deliver on this vision through:

- economical, low carbon hydrogen
- fuel cell cost reduction

10 million

fuel cell cars on the road

500,000

fuel cell buses and trucks

Hundreds

of trains and vessels

Hydrogen is most competitive in heavy duty motive applications

Our focus is on applications where hydrogen fuel cells have a clear advantage

Buses & Coaches

Trucks

Trains

Vessels

Fuel cell technology is needed to decarbonize the heavy duty transportation sector

The advantages of fuel cells over battery electric vehicles

Only fuel cell vehicles can directly replace diesel, route for route

All weather performance

Range and payload

Refueling time

Fuel cell vehicles are more adaptable

- Hybrid, scalable power system, optimized for vehicle performance
- Higher energy density enables longer routes, and heavier payloads and hotel loads
- Scalable infrastructure enables rapid deployment and scaling of EV fleets

Hydrogen fuel is widely available today. Expansion of renewable hydrogen, and advancements in hydrogen conversion are increasing renewable options.

Costs are trending down

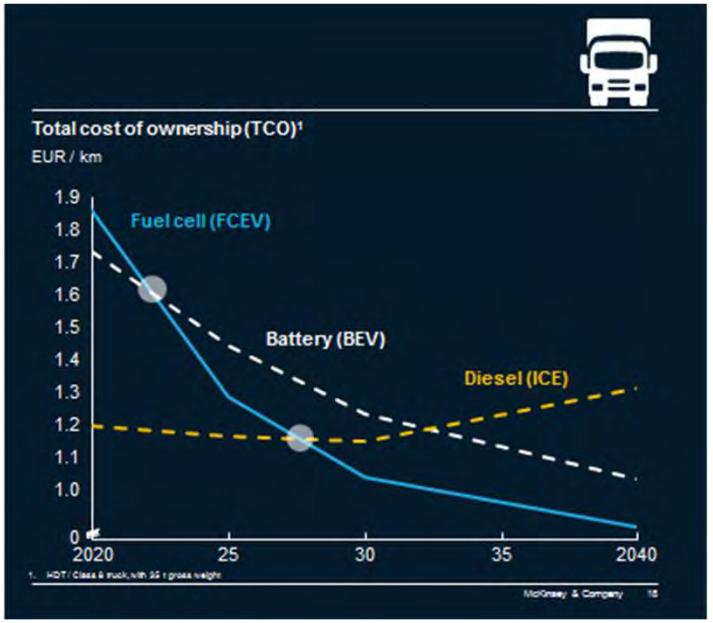
Hydrogen fuel cell transport's path to cost competitiveness

- Fuel cell system cost will drop by 70%
- Hydrogen distribution & refueling cost will drop by 40%

HDT: Commercial heavy duty transport can become cost competitive by 2030

-70%
Fuel cell system

-40%
Distribution and refueling infrastructure



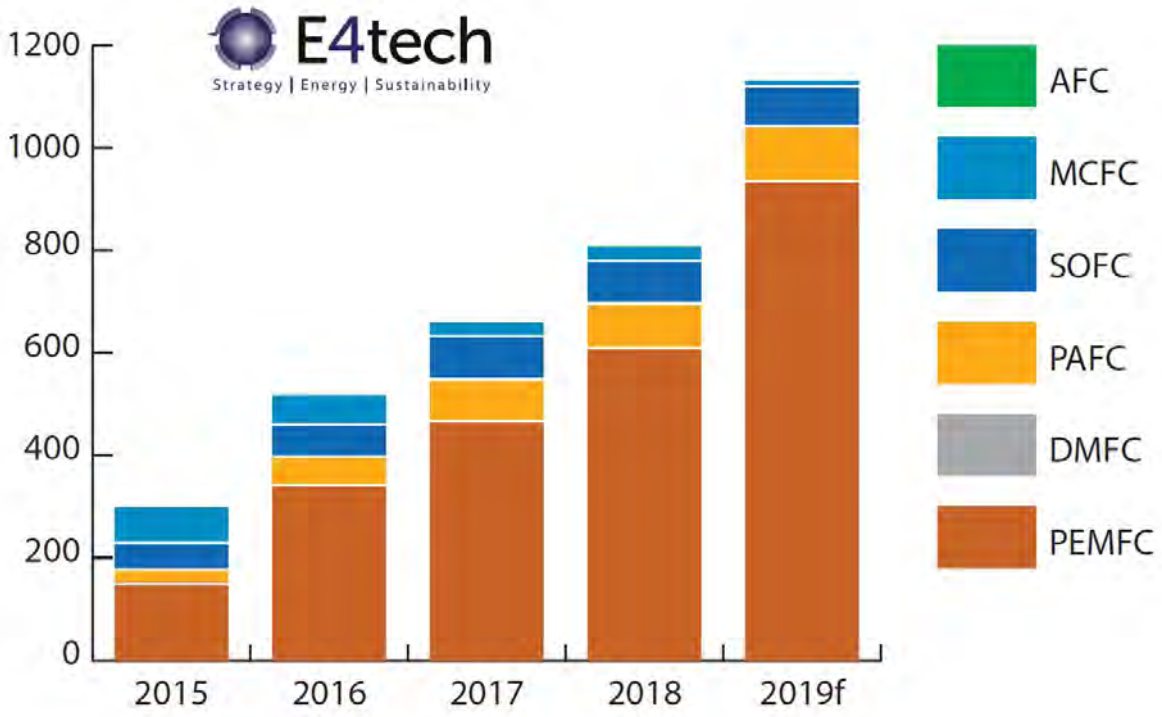
McKinsey - Path to Hydrogen Competitiveness report 2020

"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."
McKinsey - *Path to Hydrogen Competitiveness* report 2020

Fueling the Future of Mobility, Deloitte-Ballard 2020 https://info.ballard.com/deloitte-vol-1-fueling-the-future-of-mobility

PEM is the most commercialized type of fuel cell today

Its low operating temperature (50-100°C), short start time and use of atmospheric air make **PEM ideal for mobility solutions**.



MW of fuel cell shipments

Our global presence

We are present in:
Europe - China - North America

We have global industrial partners to deliver world-leading fuel cell solutions

- Office
- Sales or service presence
- Fuel cell stack & module assembly
- Bipolar plate production
- Membrane electrode assembly production

Ballard in Europe

Europe's leading fuel cell company

Strong Presence

Local Presence:

- European HQ, Ballard Power Systems Europe A/S located in Hobro, Denmark
- Location of Ballard's Marine Center of Excellence and Critical Communication Infrastructure Center of Excellence
- Manufacturing capacity of 60 MW/year

Strong Market Focus

- Local manufacturing of Ballard's fuel cell product's for marine industry (FCwave™) and critical communication infrastructure (FCgen®-H2PM)

Strong Support

- 80+ employees in Europe dedicated to sales, market development, engineering, manufacturing, service, support and training
- 60+ heavy duty vehicles in operation powered by Ballard
- 2 rail projects
- 6 marine projects
- 380 power backup systems in service

Buses
powered by Ballard

- Over 1,000+ buses deployed are powered by Ballard
- Multiple bus platforms with OEMs in Europe, US and China
- Over 25 million kilometers in service
- > 30,000 hours fuel cell stack life demonstrated

Fuel Cell Buses Worldwide

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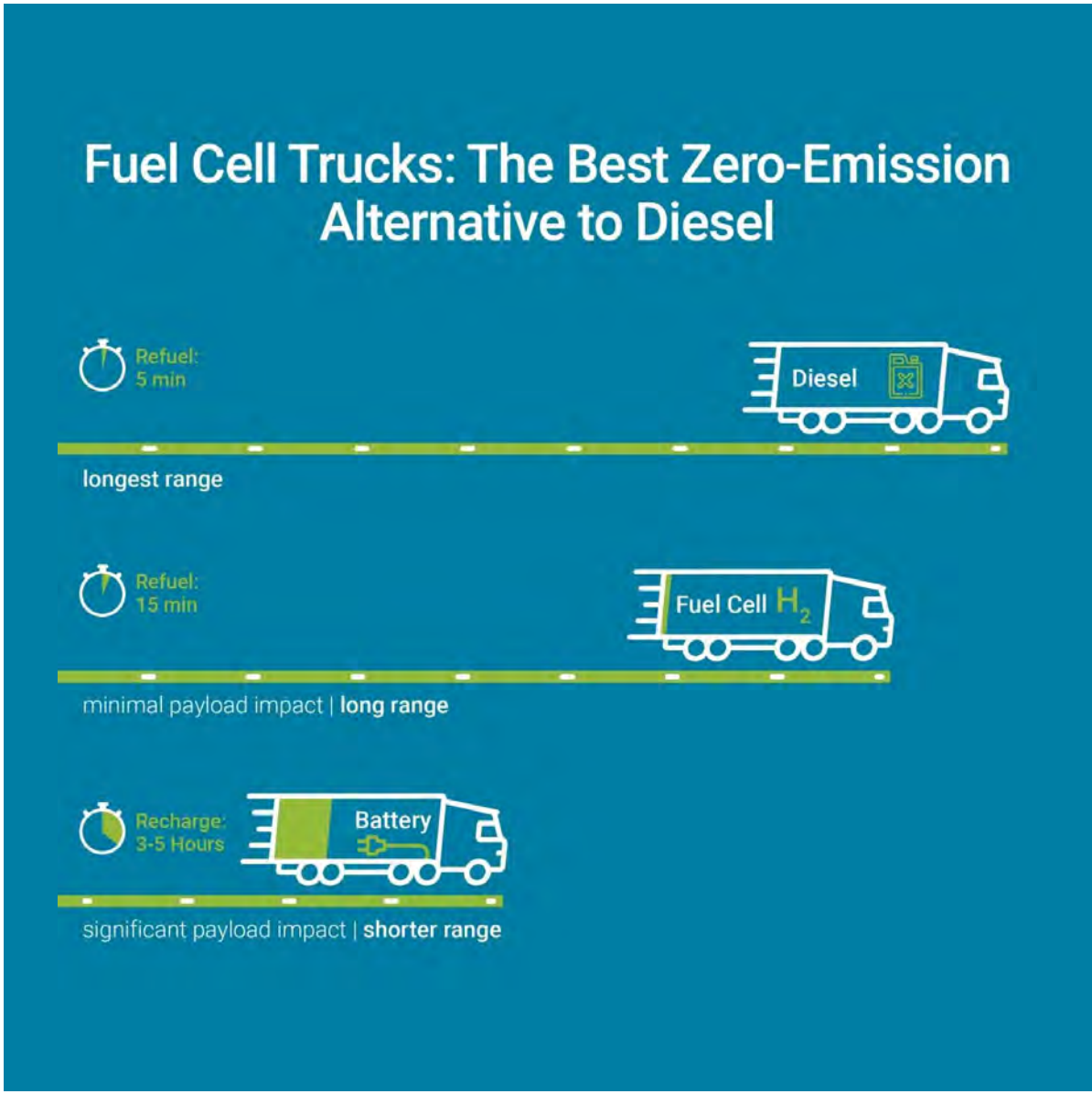
Electrification without impact on operation & profitability

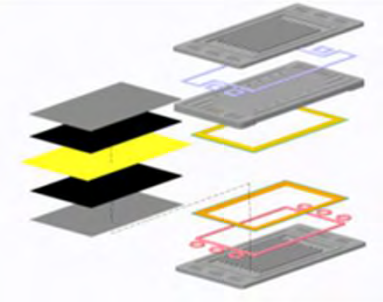
- Fuel cell trucks can haul a similar payload to a diesel truck
  - Future fuel cell truck weight reductions through lower weight storage tanks and improved integration
- Fuel cell trucks are refueled quickly to maximize revenue
  - Battery recharging downtime prevents full utilization of the truck



Trucks
powered by Ballard

- Over 2,200 urban delivery trucks
  (3 to 9 tons) in service in China
- Class 8 demonstration truck at Port of Long Beach
- UPS class 7 trucks for California
- 60t truck demonstration project – Alberta
- Refuse trucks in Europe
- Mining trucks in China and South Africa

We continuously invest in our technology and product development



Unit cell components

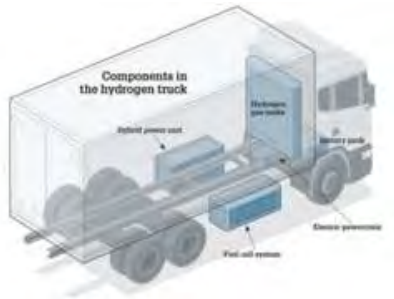
MEA, bipolar plates

Fuel cell stacks

14th generation

Fuel cell modules

8th generation



Fuel cell vehicle integration

application engineering/ after sales service

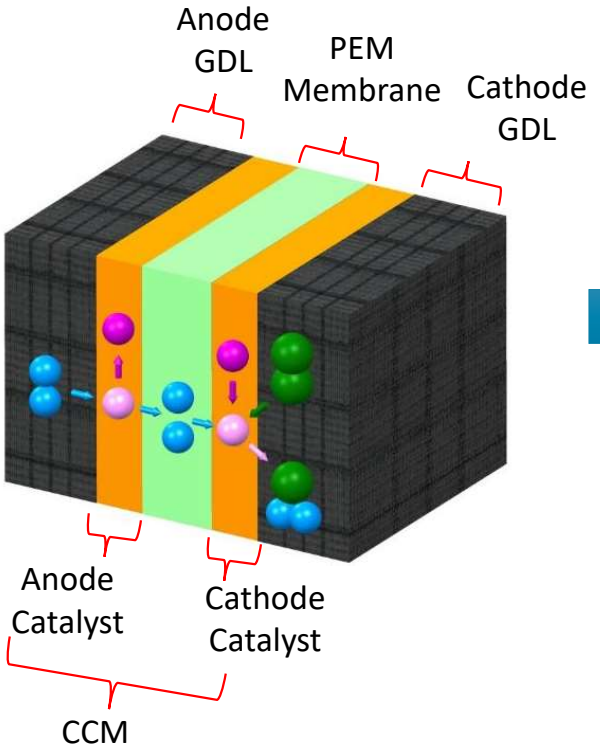
Humidified and
pressurized system

Freeze-start
from -30 °C

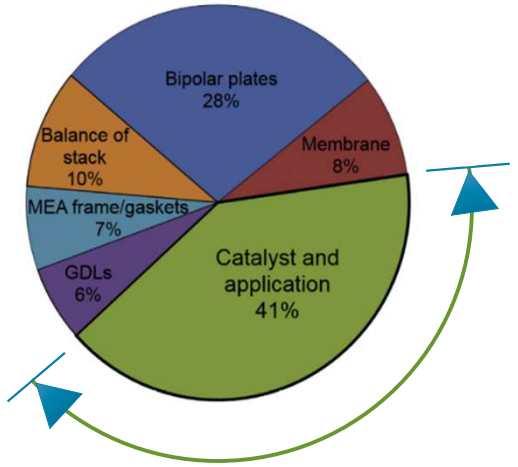
IP67
protection

>30,000 hours
life time

Membrane Electrode Assembly (MEA) Catalyst Technology: Life Cycle Cost Reduction Focus



Cost break down @ 500k stacks/year *

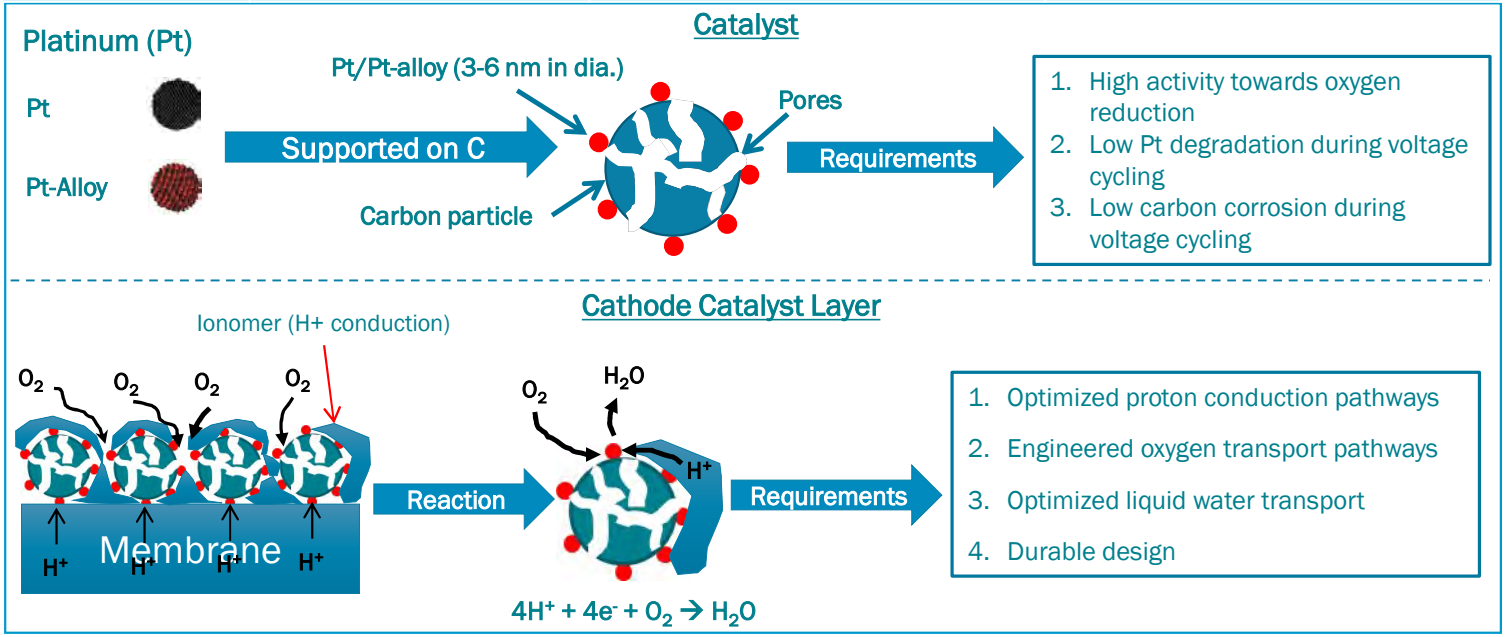


Catalyst: 41% of stack cost

* Direct hydrogen fuel cell electric vehicle cost analysis: System and high volume manufacturing description, validation, and outlook. Journal of Power Sources 399 (2018) 304–313

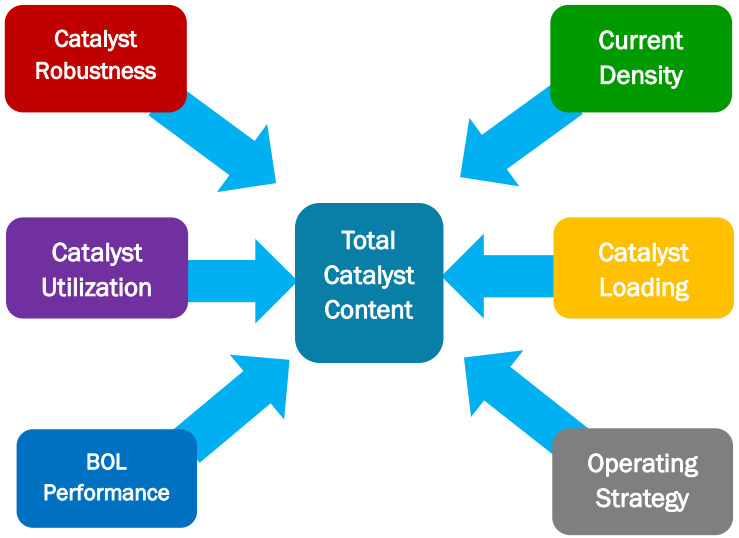
Cathode Catalyst/Catalyst Layer Design

	Key Requirements	Current Status	Technology Future
Cathode Catalyst Layer	• Produce power • Durability/stability • Liquid water transport • Gas transport	Pt alloys - high performance; - durability improvements required	Reduce Pt loading: More active/stable catalysts under development. High power O_2 transport requirements.



Approach to Precious Metal Reduction

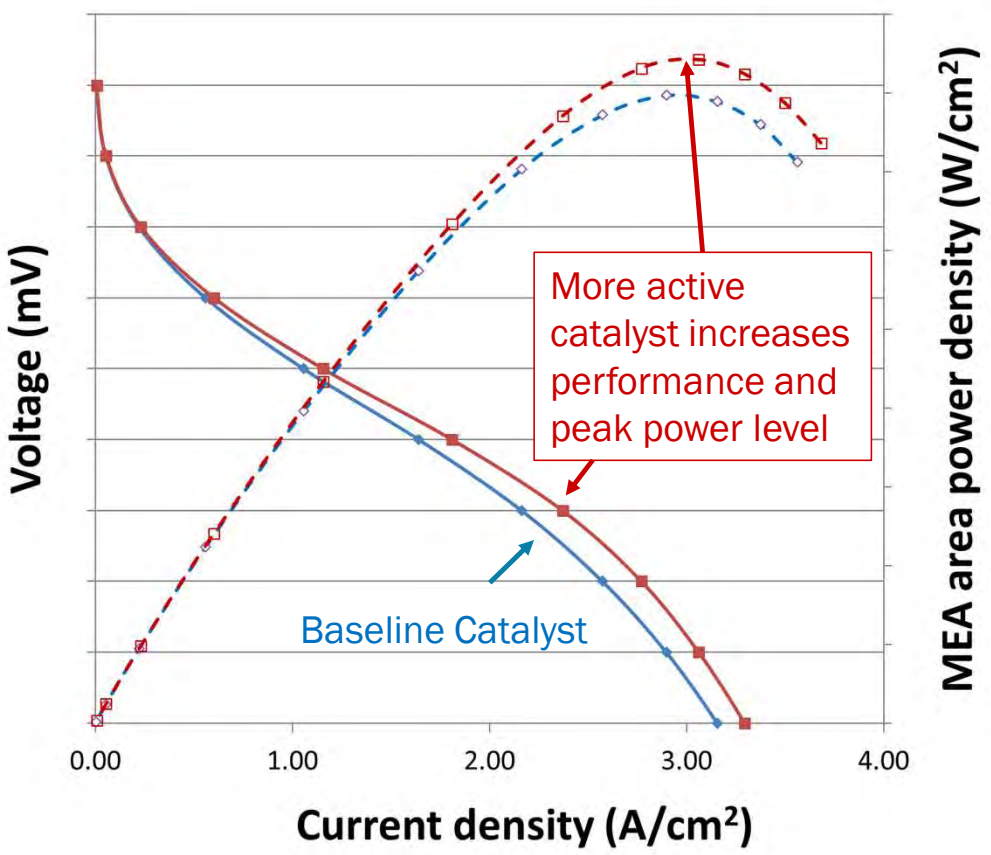
- Key limiting factor for catalyst reduction is driven by end of life (EOL) performance (performance degradation)
- Stack catalyst reduction must involve many incremental improvements
- In parallel, continuing to work on advanced catalyst technology robustness and performance



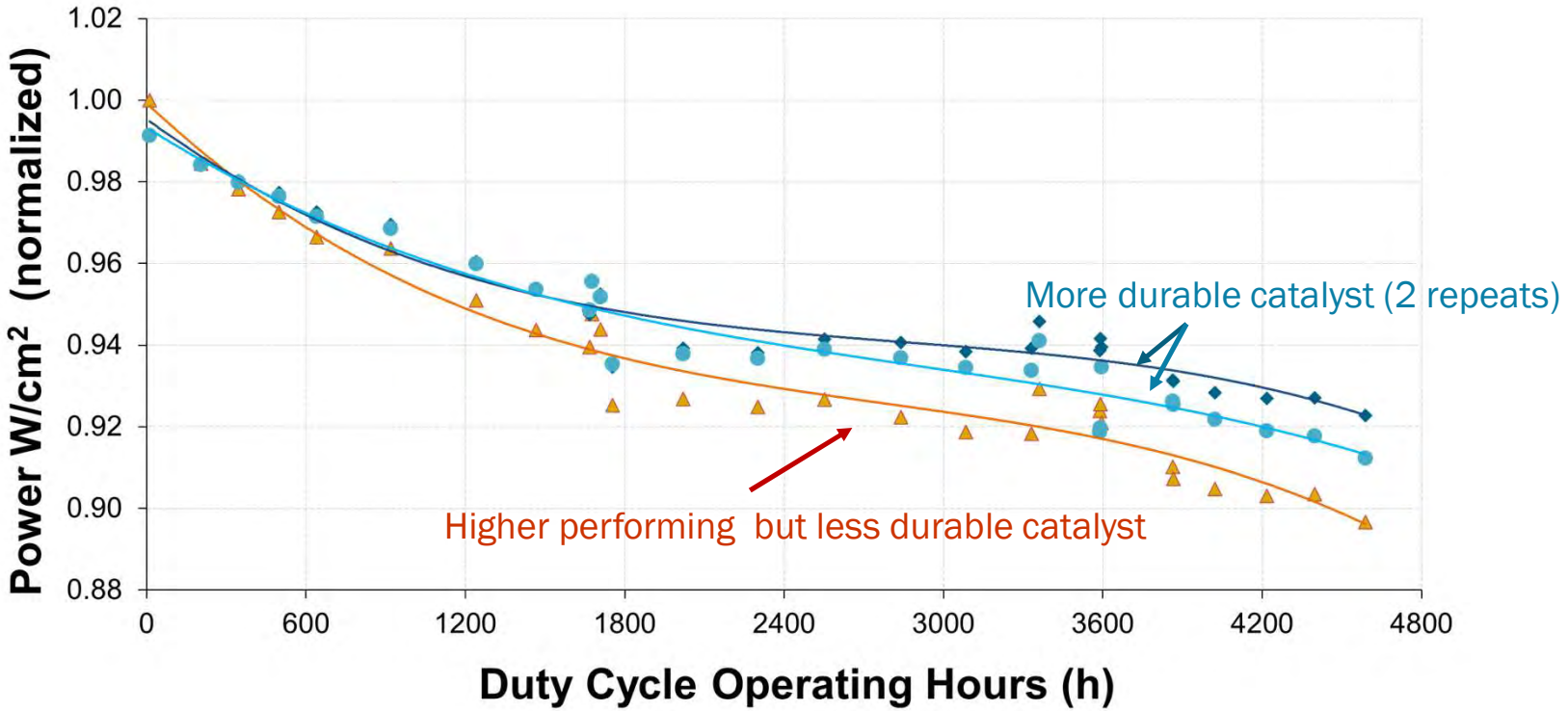
Fuel Cell Power – Catalyst Impact

Better performance:

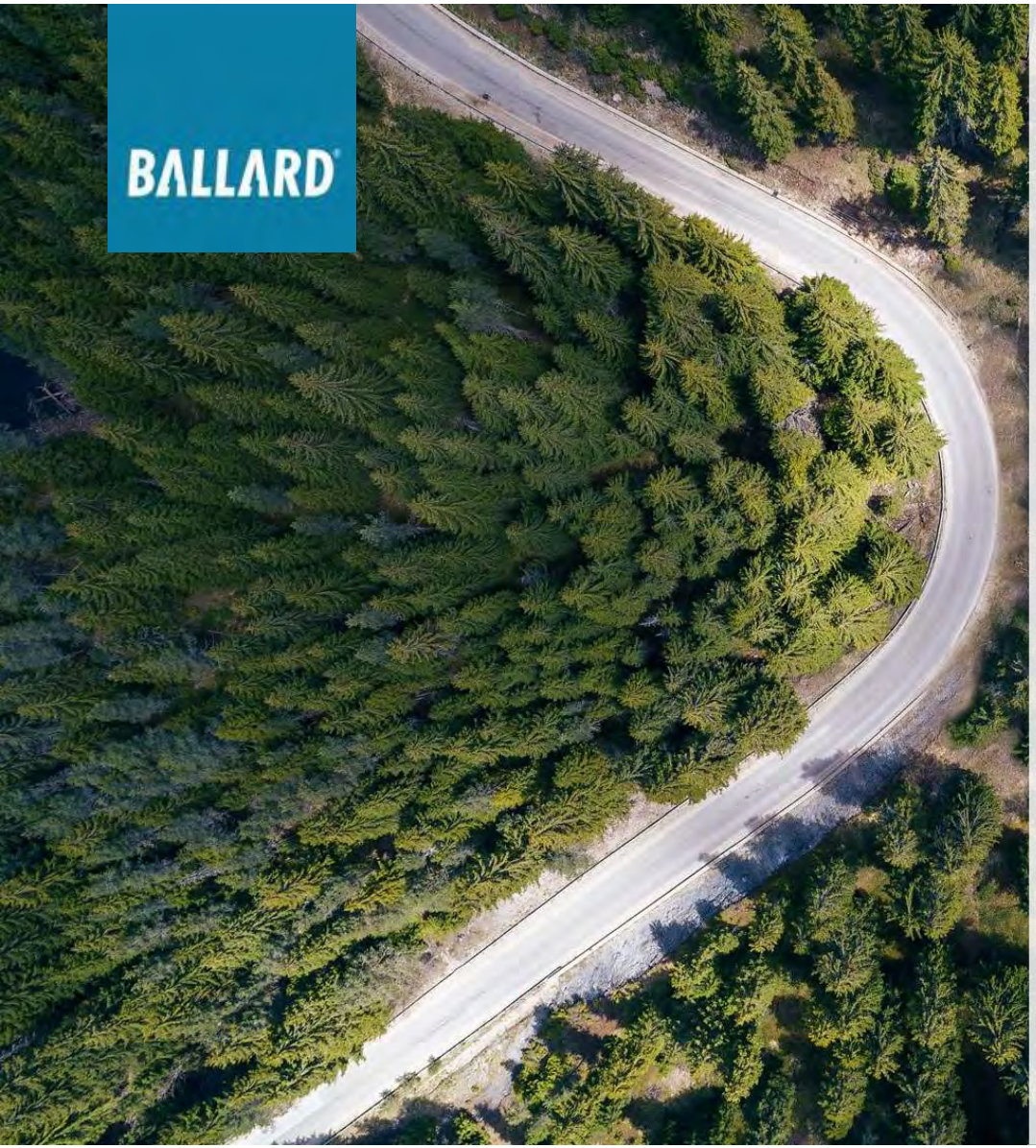
- Higher peak power obtained with more active catalyst
- Allows fewer cells to achieve the same net power, or a reduction in catalyst loading



Fuel Cell Power Durability – Catalyst Impact



Our next steps



Thank you

Please contact Shanna Knights
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Ballard.com

Power to Change the World®