

**BALLARD™**

# Powering the Future of Rail with Hydrogen

Name

Title

Date



# Agenda

- What about Hydrogen?
- Ballard Power Systems - Fuel Cell Innovator for over 40 years
- Ballard Power Systems – your sustainable partner
- From Road to Rail
- Ballard Power Systems Rail Product Portfolio
- Project examples and customer references



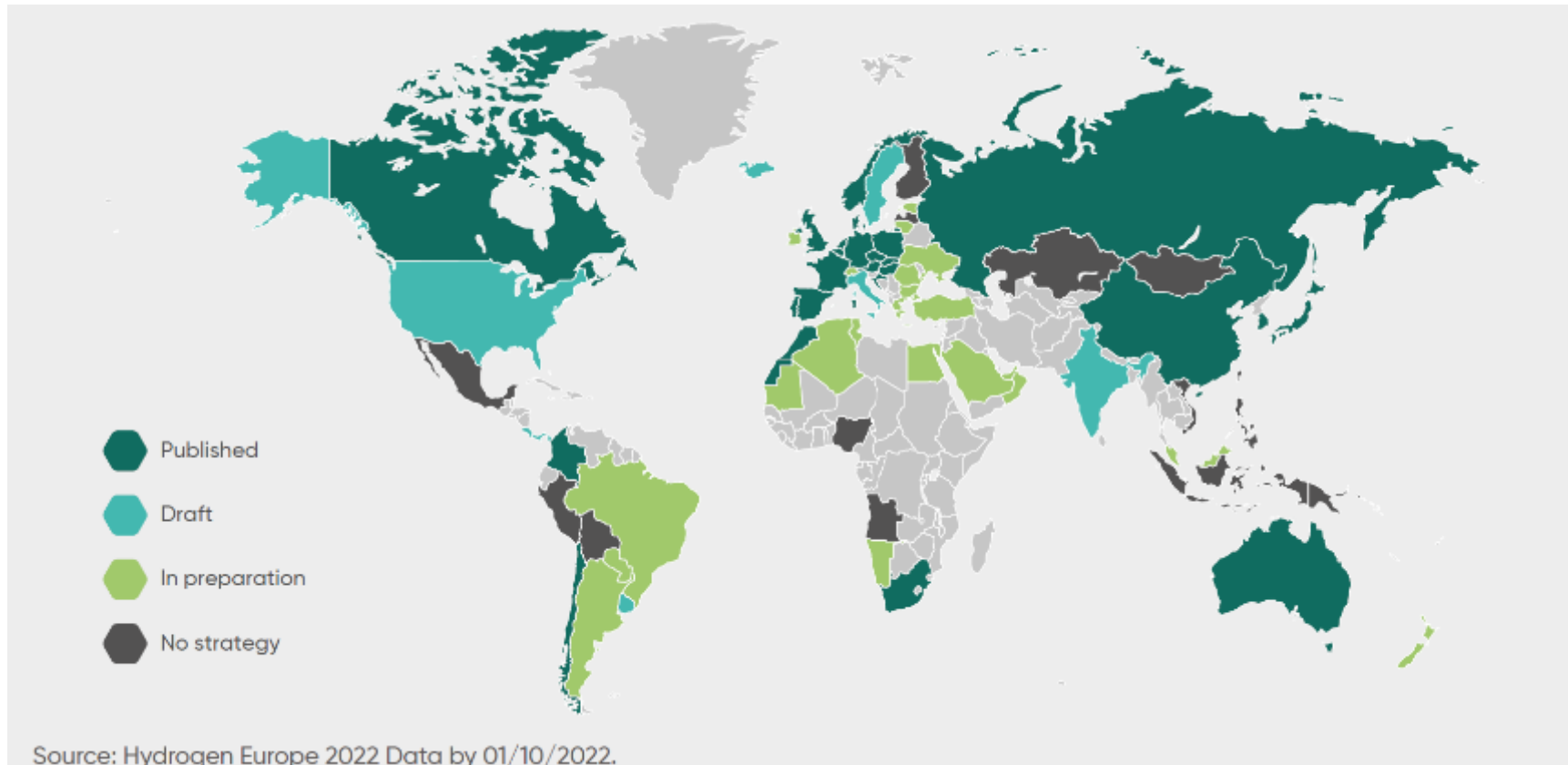


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Hydrogen

# There is no climate solution without hydrogen

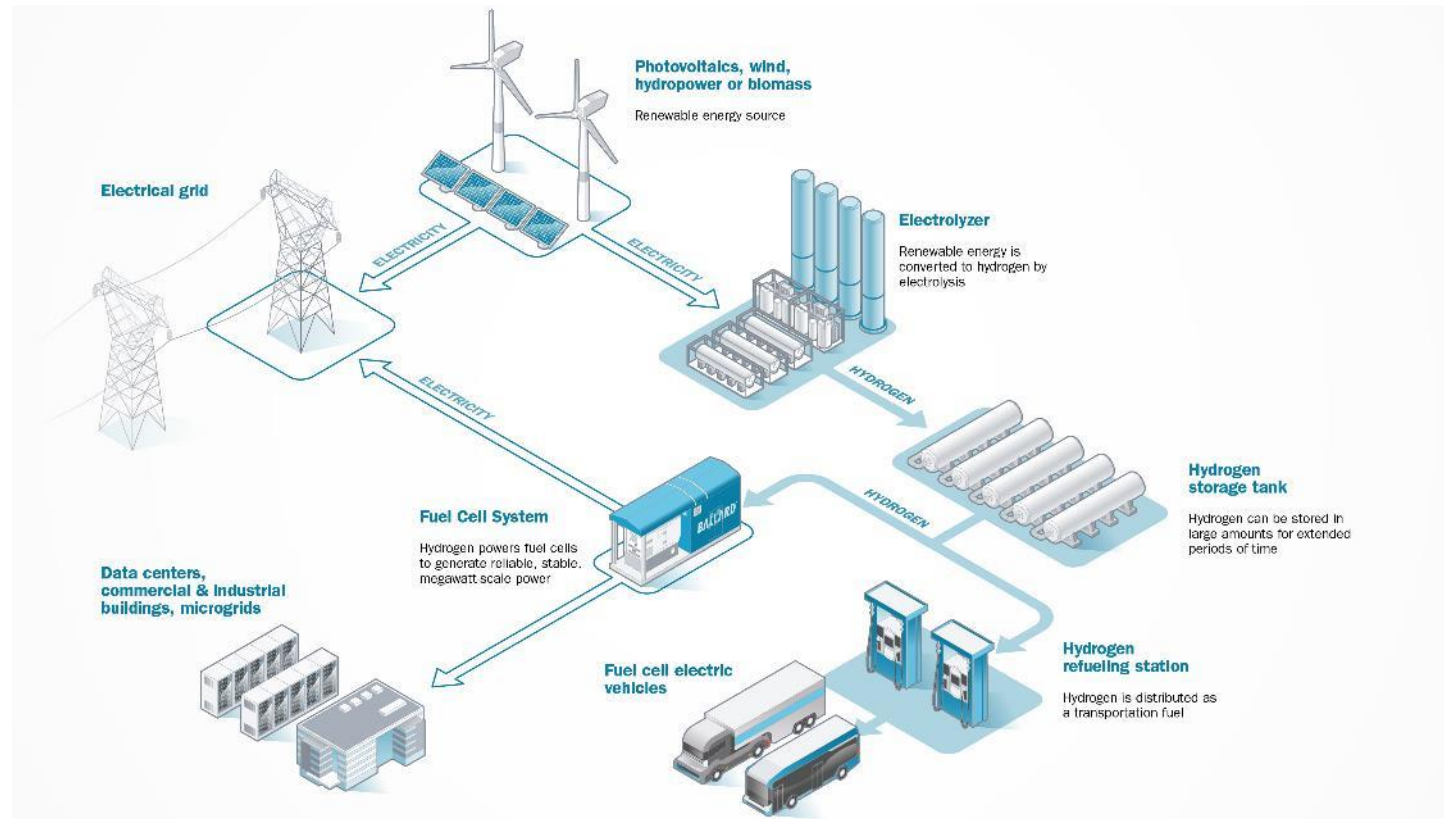


- **50 countries** have developed hydrogen strategies, road maps or are supporting national projects
- **Over 520** large scale green hydrogen projects announced to date
- **Near 150** members in the Hydrogen Council globally since 2017



# Hydrogen is key to the decarbonization of our economy

- Hydrogen is the **energy carrier** to decarbonize multiple sectors and change the future industry
- Supported by electrolyzing technology hydrogen is an important **storage solution** for renewable energy that cannot be distributed by the grid
- Hydrogen is a flexible **low or zero carbon fuel** for mobility
- Stationary hydrogen fuel cells provide **energy on demand** for various sectors, e.g., backup power, grid balancing or power to power



# 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



Ships

*Fuel cell technology is essential to decarbonize the heavy duty transportation sector*

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



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## Hydrogen powered trains are poised to change the rail industry

The environmental gains of electrification with performance and refueling time comparable to diesel



Short refueling time



Long range and route flexibility



Cost effective route electrification





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Ballard Power Systems  
Fuel Cell Innovators for  
over 40 Years



The Ballard logo, featuring the word "BALLARD" in a bold, white, sans-serif font with a trademark symbol, set against a dark blue square background.

## Ballard Power Systems

We are dedicated to accelerate the adoption of fuel cell technology



## Proven

44 years of fuel cell deployments in diverse applications bring experience, scale, service and lifecycle cost expertise advantages

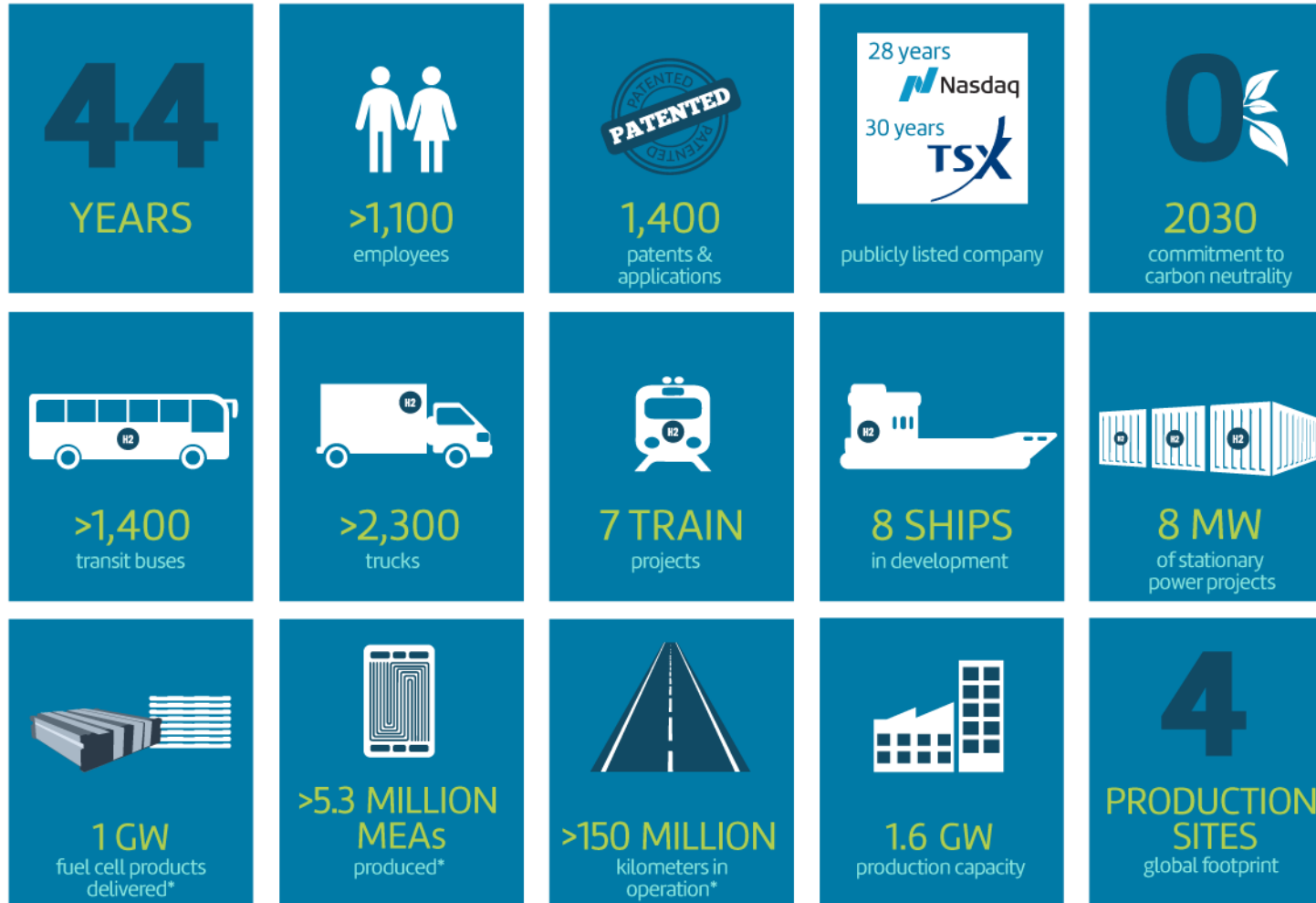
## Performance

Leading Fuel cell efficiency, durability and reliability  
Products developed according to industry standards

## Promise

End to end support from engineering, testing, after sales services & training  
Sustainable zero-emission solution

# Ballard by the numbers



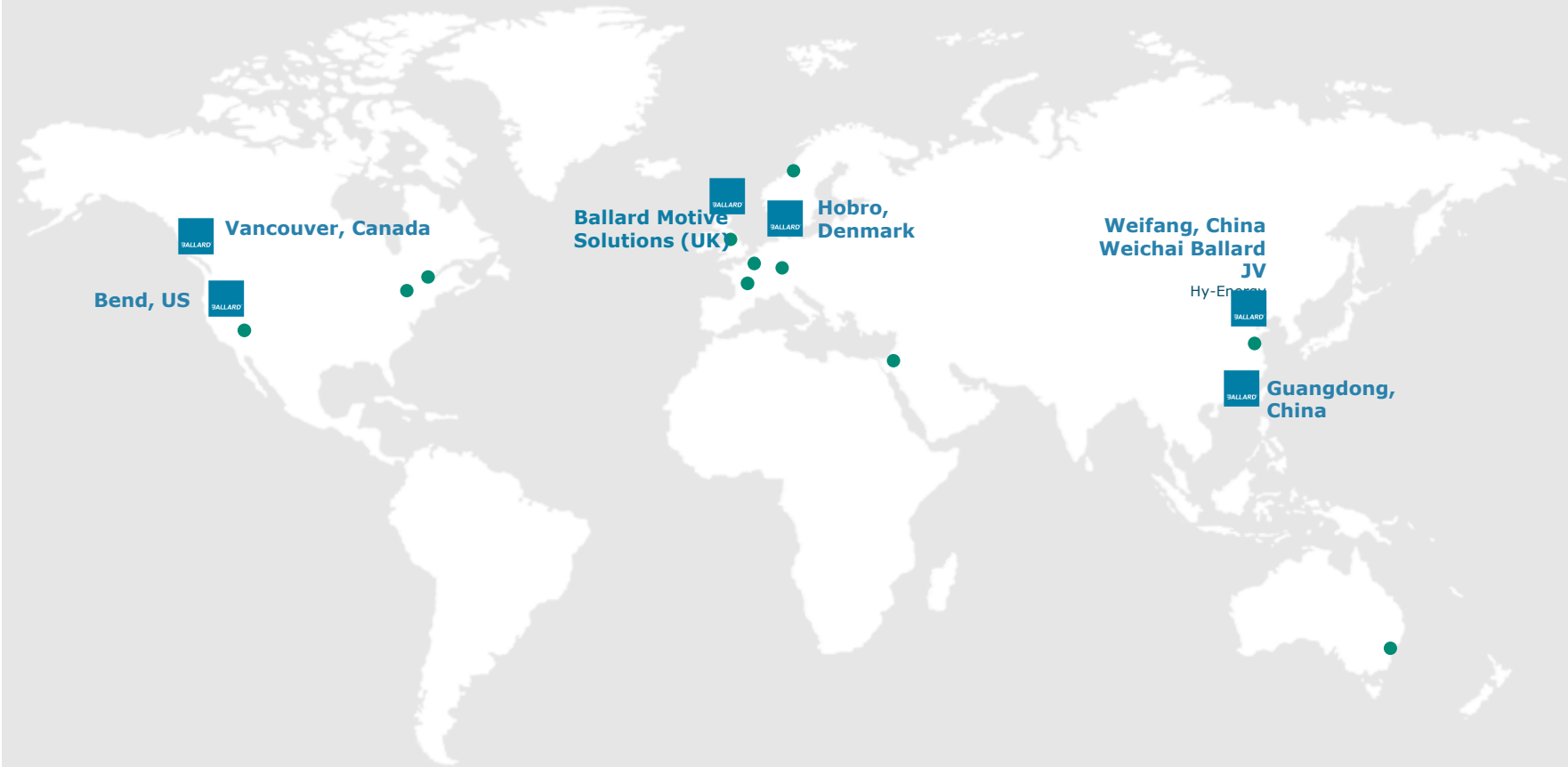




# Our global presence

**We are present in:**  
Europe - China - North America

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



Manufacturing or R&D site



Sales, Marketing and/or service presence

# We support our customers through their journey



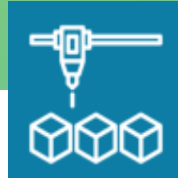
## Consultancy

- Over 40 years experience
- Customer references
- Sales resources
- Educational tools
- Subject matter experts
- Market analysis & financial services



## Applications engineering

- FAT & SAT
- Vehicle integration support
- Simulations
- System integration



## Engineering services

- Testing & certifications
- Product design
- Technology transfer
- Strong IP



## Manufacturing

- Four global production sites
- State-of-the-art prototyping & high-volume equipment



## Training

- Fuel cell technology knowledge
- Product operation and maintenance
- Remote or onsite classes
- Market analysis







## After-sales services

- On site support
- Spare parts
- Call center
- Service contracts



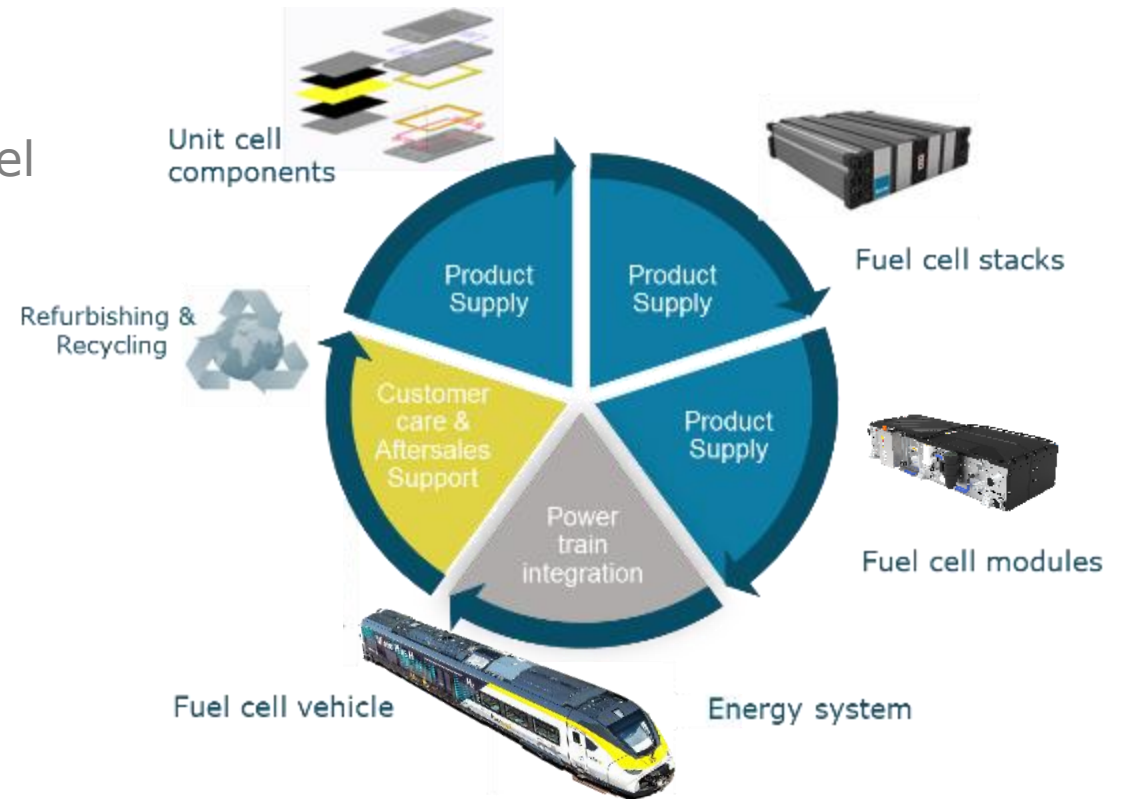
# We have a comprehensive range of fuel cell products to address multiple applications

Product Line		Specifically designed for the application
From low to high level integration	Fuel cell <b>components</b>	MEAs and bipolar plates 
	Fuel cell <b>stacks</b>	Air and liquid cooled stacks from 400W to 140kW 
	Fuel cell <b>modules</b>	Heavy duty power modules from 45kW to 200kW 
	Complete fuel cell <b>systems</b>	Stationary systems from 2.5 to 5kW and 200kW to MW's 
	Energy <b>System</b>	Controller

# We are a vertically integrated manufacturer throughout the fuel cell value chain

We design, build and test proprietary core technology components to produce optimized fuel cell products for each application

- Unit cell components (MEAs, plates...)
- Fuel cell stacks
- Balance of plant component integration
- Fuel cell module & system
- Energy systems and powertrain integration



Supporting our customers throughout the product life cycle



# Product development continually focuses on meeting performance and lifecycle cost targets



Continually refining Customer requirements



Modularization and standardization of components and subsystems



Foster innovation



Production orientated design refinements



The Ballard logo, consisting of the word "BALLARD" in a white, bold, sans-serif font with a trademark symbol, is positioned in the top left corner of the image. It is set against a solid blue rectangular background.

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The background of the entire image is a photograph of railroad tracks curving through a lush, green, hilly landscape. The tracks are made of steel rails on wooden ties, with gravel ballast. The scene is captured from a low angle, looking down the tracks as they curve into the distance. The lighting is bright, suggesting a sunny day.

Ballard Power Systems  
your sustainable partner



**BALLARD™**

Because ...



We offer zero emission solutions - from stack supply to turnkey power solutions at MW scale



Our technology is proven with over 1GW of fuel cell products shipped and serviced to date



Major top global partners have signed up and trust in our partnership



We have a clear road map to drive cost reduction and meet commercialization targets

Why Ballard?



The Ballard logo, featuring the word "BALLARD" in a bold, white, sans-serif font on a blue rectangular background.A circular icon with three arrows forming a triangle, representing the "REUSE, REDUCE, RECYCLE" principle. The text "REUSE REDUCE RECYCLE" is written vertically to the right of the icon.

REUSE  
REDUCE  
RECYCLE

To ensure sustainability is considered over the entire lifecycle of our products

At Ballard we:

Design our product to minimize carbon footprint

Refurbish fuel cell stacks at the end of life

Re-use graphite bipolar plates

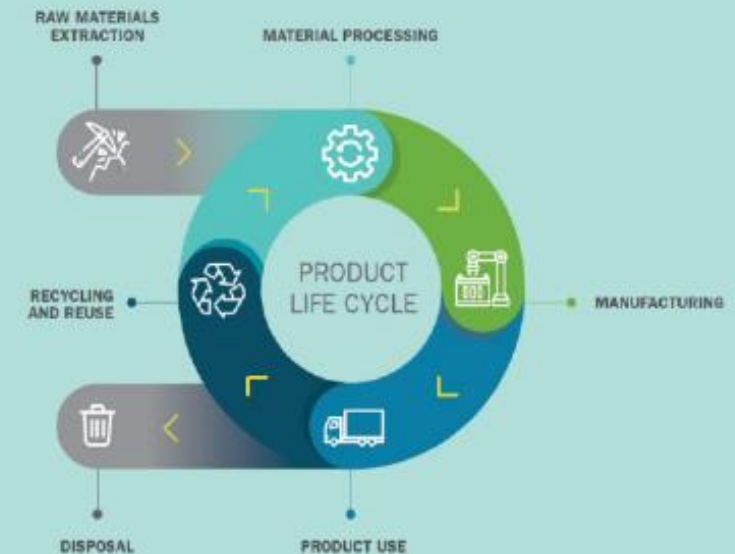
Reclaim 95% of the platinum

We are committed to be carbon neutral by 2030



>95%

Precious metals are reclaimed during recycling



Cost savings for the customers as a result of refurbishing



# Sustainable power from a sustainable company

Ballard Environmental, Social  
and Governance (ESG)  
Report 2021

[https://www.ballard.com/about-  
ballard/our-sustainability](https://www.ballard.com/about-ballard/our-sustainability)



2030 net zero  
emission initiative

Reducing the  
environmental  
footprint of our  
operations

Reducing our fuel  
cell product carbon  
footprint

Ballard to be net  
zero by 2030



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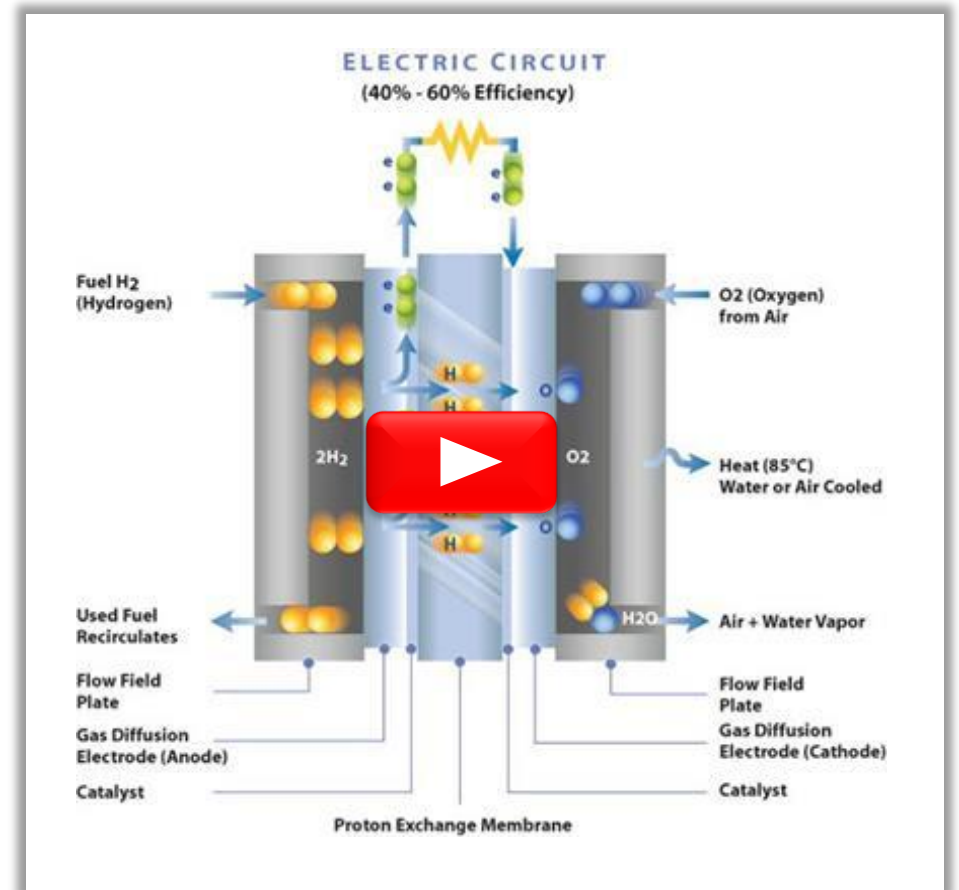
Ballard Power Systems  
your sustainable partner



# Why Fuel Cells and how does it work?

## PEM Fuel Cells

- help the transition away from fossil fuels
- create zero emissions
- generate reliable DC power when required
- are highly efficient
- support various duty cycle applications
- Provide rapid ramp-up/down to follow load



# Fuel cell systems are scalable to a variety of routes and applications

## Passenger



- 400kW fuel cell power demand
- Workload 80t
- Max. speed 160km/h

## Locomotive



- 1.2MW fuel cell power demand
- Workload 30t
- Avg. speed 35km/h

## Shunter



- From 170kW+ fuel cell power demand
- Workload 70t
- Max. speed 90km/h

## Tram



- 400kW fuel cell power demand
- Workload 80t
- Max. speed 70km/h

Nearly any train route served by diesel trains can be served by a hydrail train

- No requirement for overhead catenary infrastructure and power substations
- Enables gradual electrification (one train at the time) aligned with budget availability



ZERO  
EMISSION



Lower CAPEX on non-electrified tracks



Flexibility and range



Low OPEX



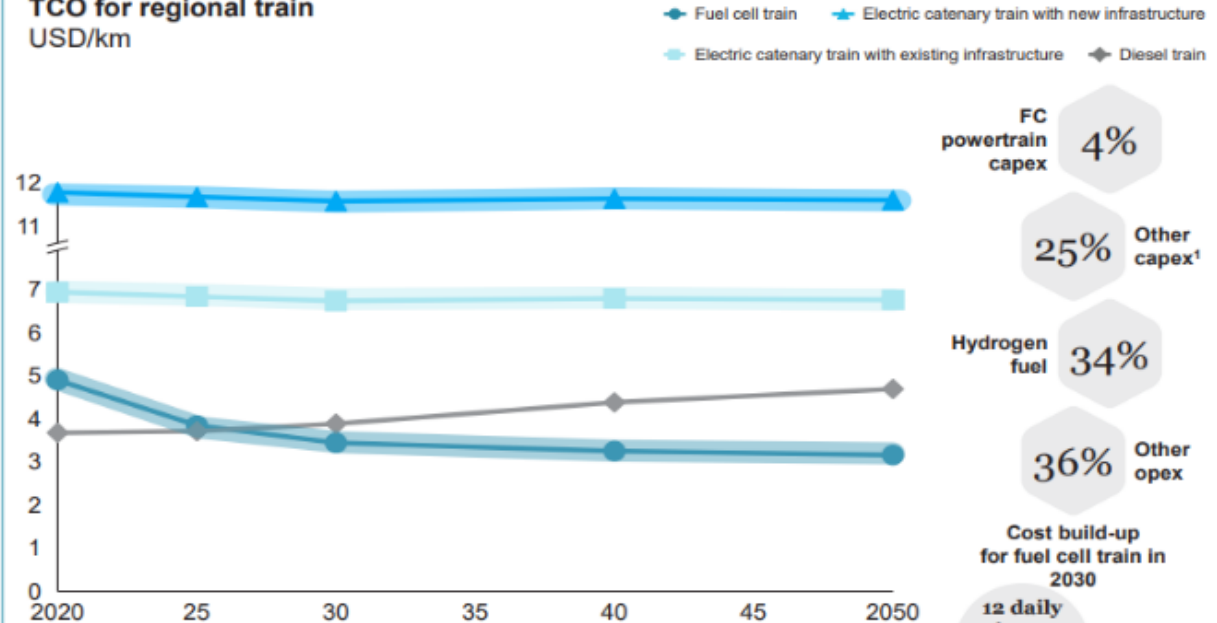
# Cost effective route electrification

“The hydrogen train is already more competitive than electric catenary for a use case with relatively long distance and low frequency.”

*Hydrogen Council, 2020*

**Exhibit 23 | TCO trajectory of regional trains**

**TCO for regional train**  
USD/km



FC powertrain capex **4%**

Other capex<sup>1</sup> **25%**

Hydrogen fuel **34%**

Other opex **36%**

**Cost build-up for fuel cell train in 2030**

- Lifetime **30 years**
- Passenger capacity **150**
- 12 daily trips per train** (15 hours operation)
- 4 trains** going back and forth on 100 km double track

1. Other capex includes hydrogen tanks, inverters, battery, and electric motor, in addition to the train itself

SOURCE: McKinsey

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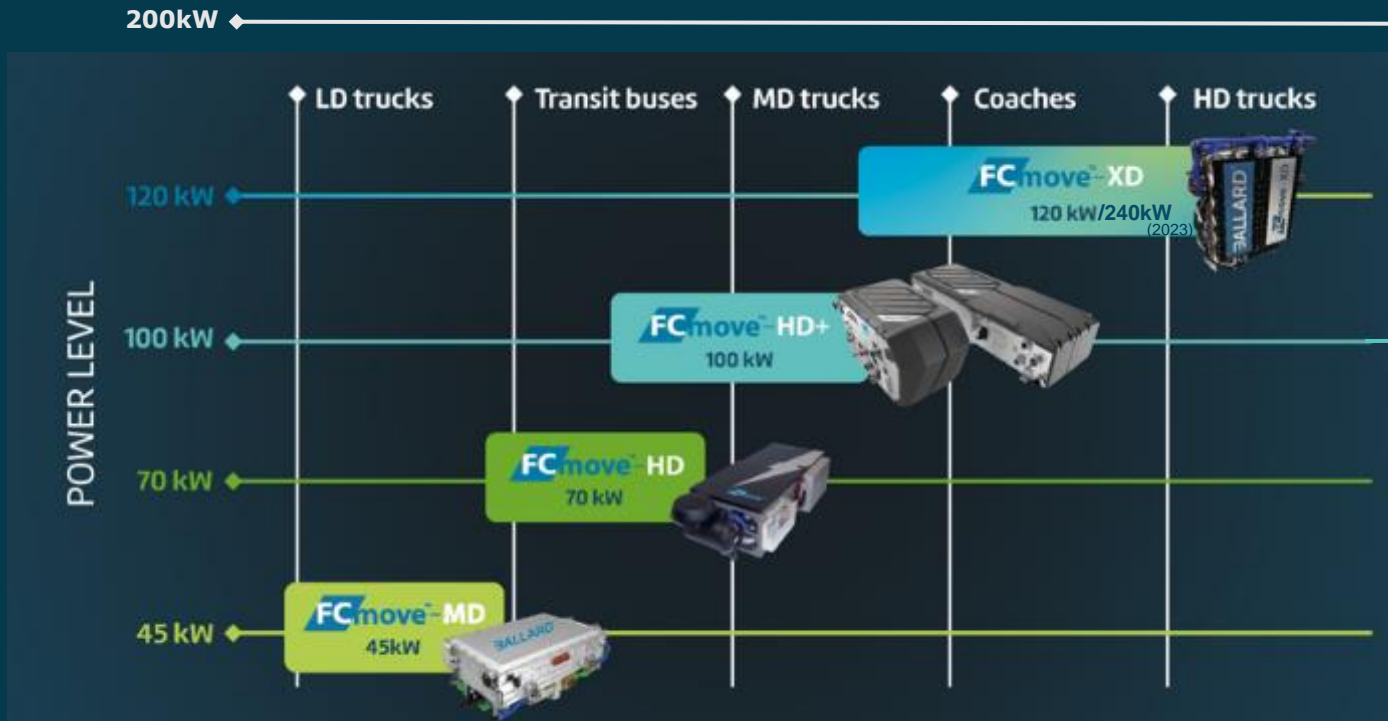
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The title text is centered on a large, semi-transparent graphic overlay that transitions from light green on the left to dark blue on the right. The text is in a white, sans-serif font.

Ballard Power Systems  
Rail Product Portfolio

# A dedicated portfolio of products for heavy duty mobility

## Bus & Truck



## Marine & Rail

**FCwave<sup>™</sup>-XD+**  
200 kW

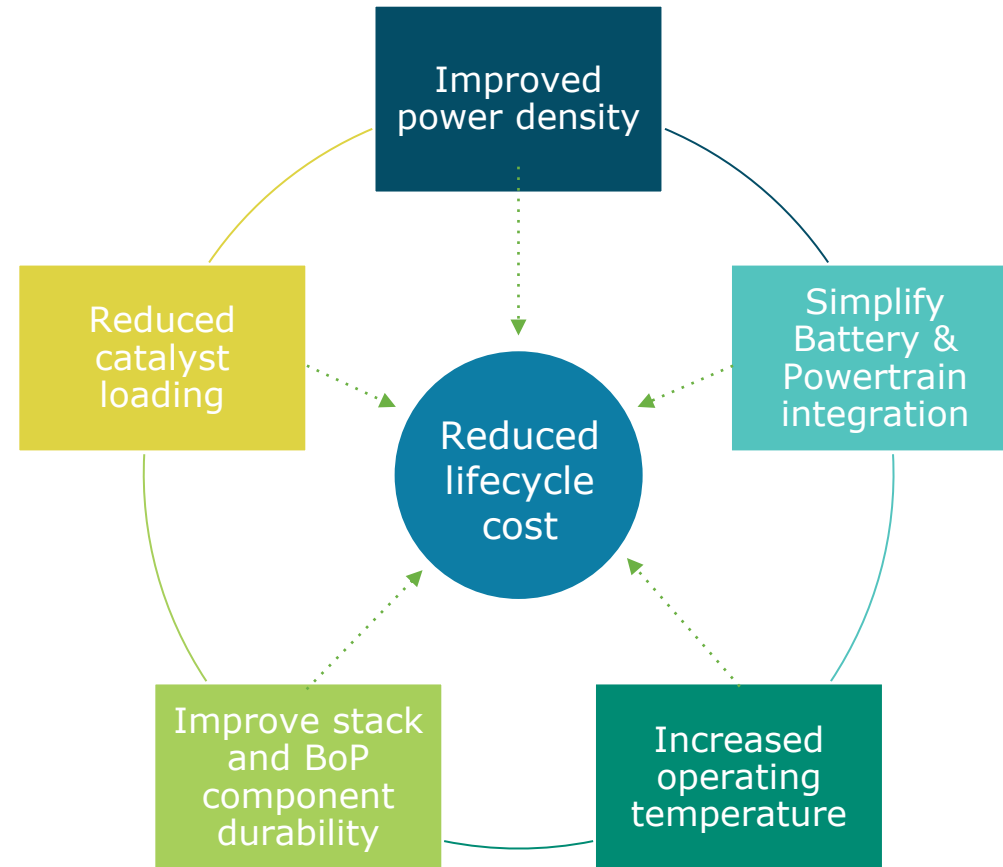


**FCrail<sup>™</sup>-HD+**  
100kW (2025)



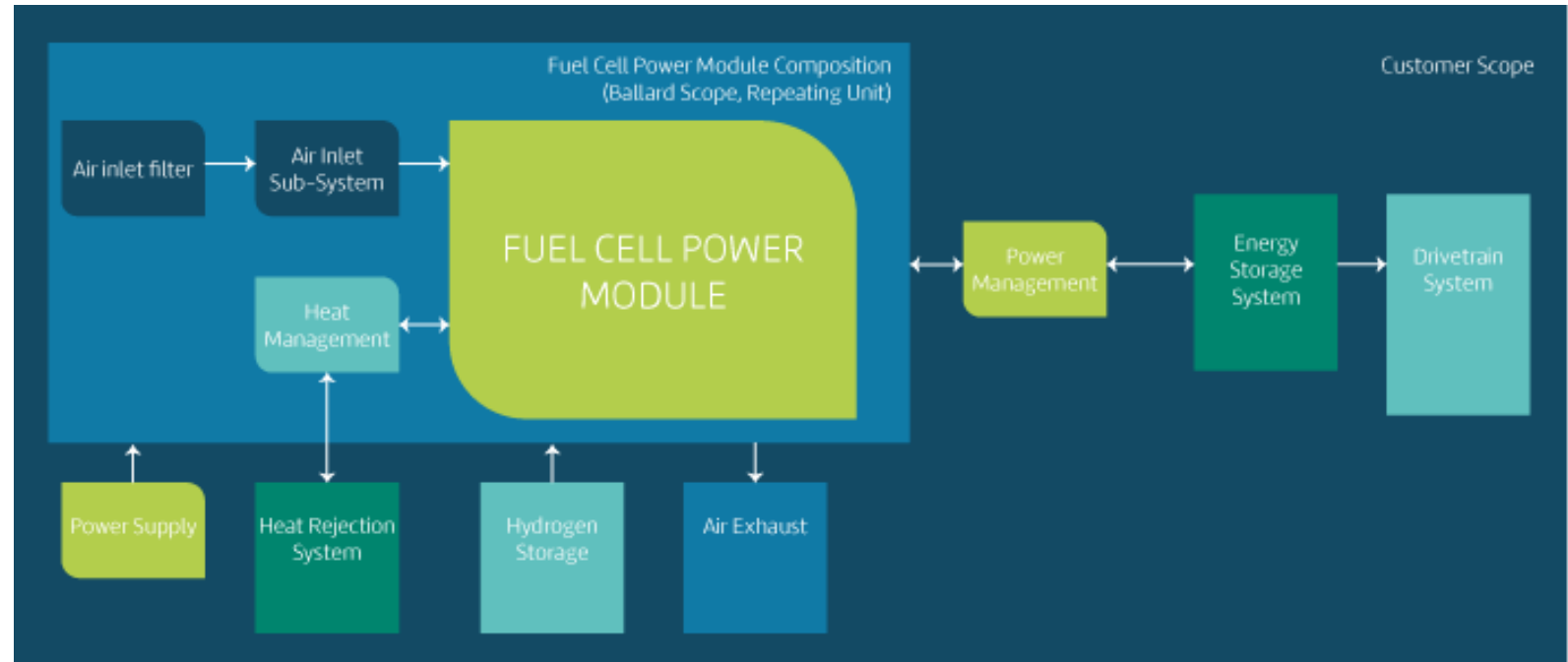


# Product development focuses on meeting performance and lifecycle cost targets



# FCrail™-HD+ Module

- 100kW building block fuel cell power modules
- Multiple units installed in flexible configuration to meet power requirements
- Designed and tested to rail-specific standards
- Proven fuel cell stack durability (over 30,000h in FC bus application service)



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Project examples and  
customer references



## Trains powered by Ballard

- Ballard to Power Sierra Northern Railway Switching Locomotive in California
- Ballard Announces Order for Modules to Power Scotland's First Fuel Cell-Powered Train
- Ballard to Power Talgo Fuel Cell Passenger Train in European Trial, Ahead of Planned 2023 Launch
- Ballard Fuel Cells to Power Expansion of Canadian Pacific Hydrogen Locomotive Program
- Ballard to power India's first hydrogen trains
- Ballard receives order from Siemens Mobility to power 7 trains and signs LOI for up to an additional 200 modules over the next six years
- Ballard inks contract with Stadler to supply fuel cell engines to power first hydrogen train in United States





# Case Study: Foshan Gaoming Hydrogen Tram Line

Rolling Stock OEM	CRRC Qingdao Sifang
Application	5 fuel cell trams
Region	Gaoming District, Foshan City, China
Ballard product	FCveloCity®-XD, 200kW
Start of operation	December 2019
Max. passenger capacity	394
Max. Range per refueling	125km
Total kilometers driven	>425,000km*
Top speed	70km/h

\*status January 2023



# Case Study: Siemens Mireo Plus H

Rolling Stock OEM	Siemens
Rail Platform	Mireo Plus H
Application	passenger train
Region	Berlin-Brandenburg (D)
Ballard product	2 x FCrail™-XD+ SE, 400kW
Planned start of operation:	December 2024





# Case Study: CP Rail Hydrogen Locomotive Program

Rolling Stock OEM	CP Rail
Locomotive Platform	converting diesel-electric powertrains to hydrogen-electric powertrains
Application	line-haul freight locomotive
Region	Alberta, Canada
Ballard product	6 x FCwave™, 1.2MW
Timeline	2021 - 2022



# Case Study: PESA Shunting Locomotive

<b>Rolling Stock OEM</b>	<b>PESA</b>
Locomotive Platform	SM42-6Dn locomotive
Application	Shunting locomotive
Region	Płock ,Poland
Ballard product	2 x FCveloCity™-HD85, 170kW
Timeline	August 2022 – April 2023



# Case Study: Stadler Flirt H2 first hydrogentrain in the US

Rolling Stock OEM	Stadler
Rail Platform	Flirt H2
Application	passenger train
Region	San Bernardino, CA (USA)
Ballard product	6 x FCrail™-HD+, 600kW
Timeline	2023 - 2024





A young child with curly hair is looking out a train window at a sunset. The child is wearing a blue shirt and a purple jacket. The train window shows a landscape with a sunset over a field.

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*Here for life™*

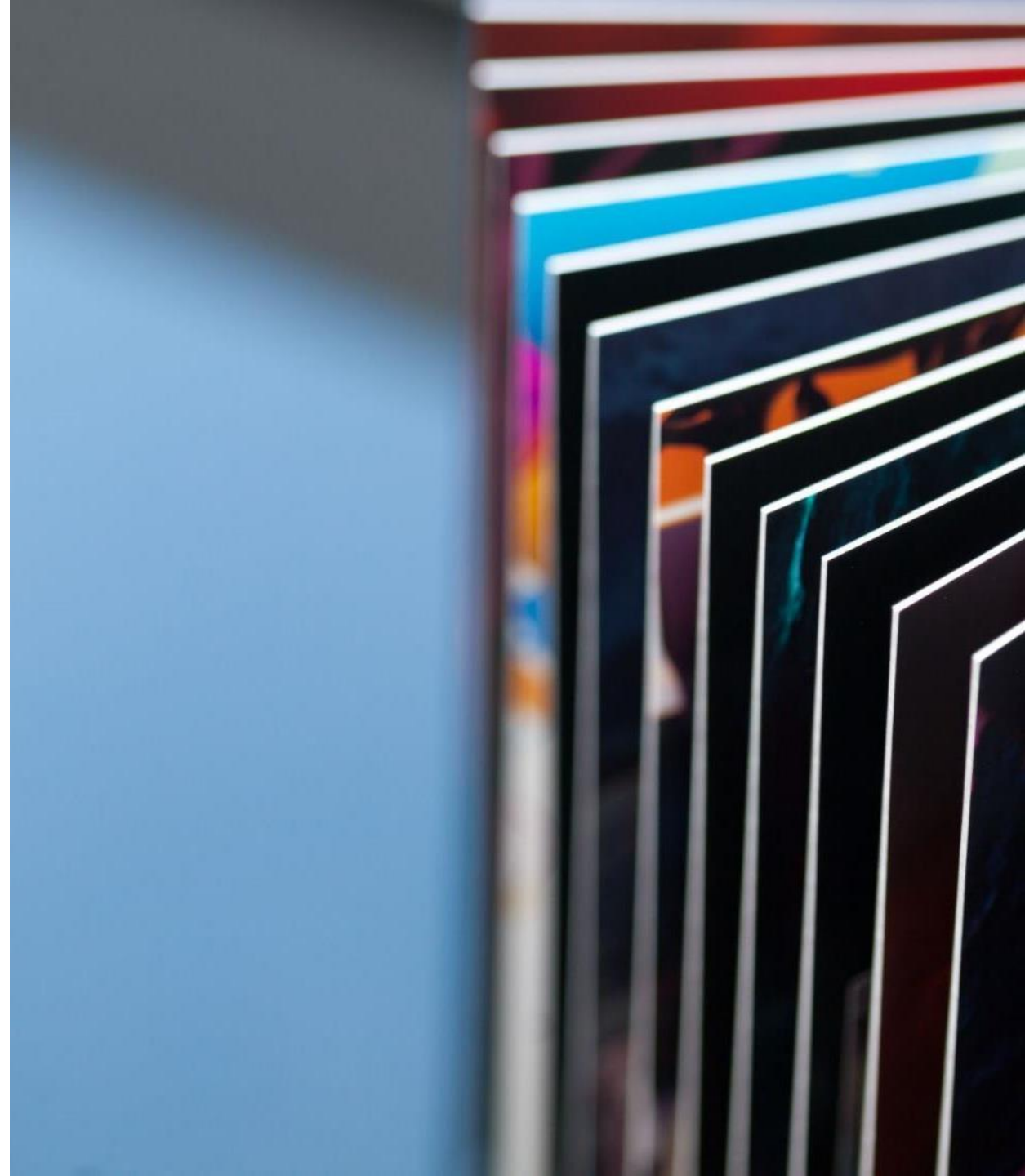
Thank you

Ballard.com

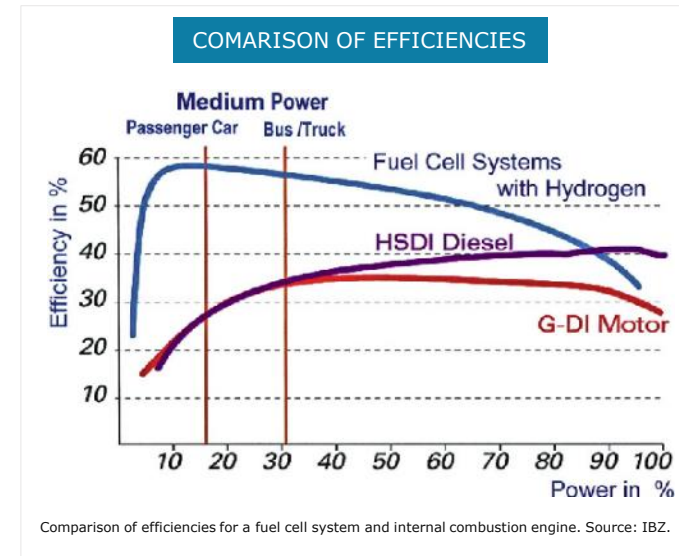
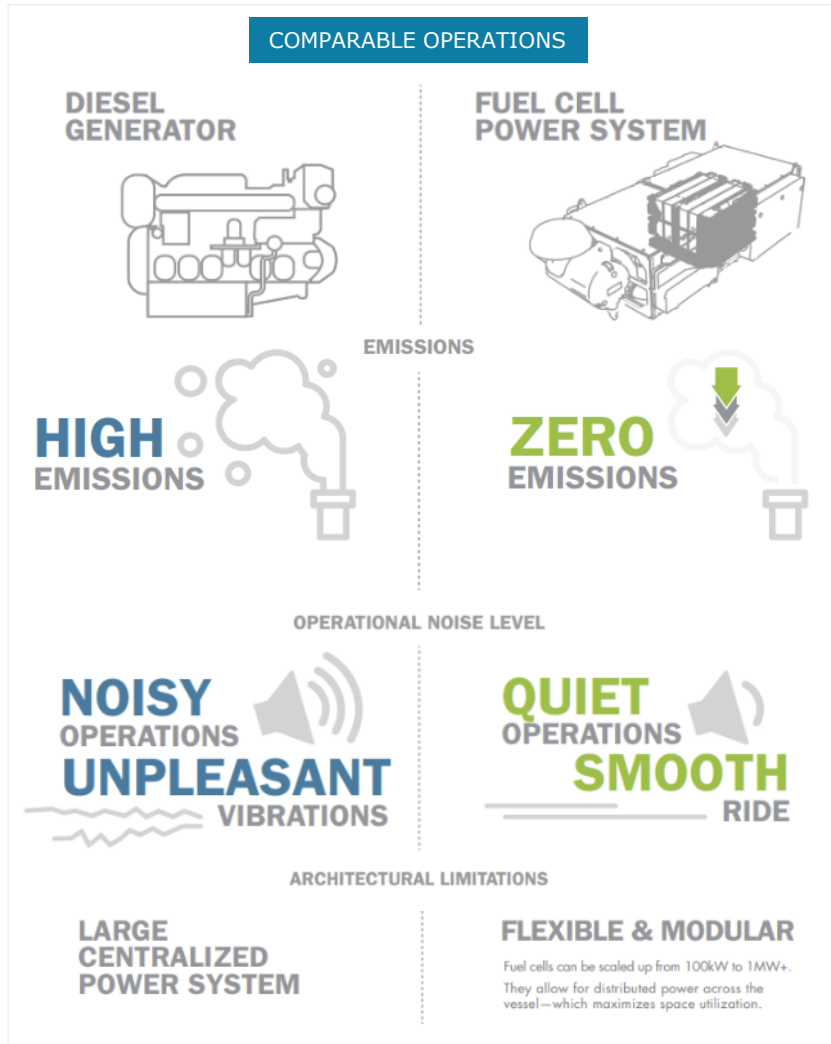


## Additional Slides

- Infographic Hydrogen Fuel Cell vs. Diesel
- Ballard region North America
- Ballard region Europe
- Ballard region China



# Hydrogen Fuel Cell vs. Diesel Technology





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# Ballard in North America

Location of corporate headquarters



**Vancouver, Canada**  
R&D & Production  
Service center  
MEA, Stacks, Motive



**Bend, US**

## Strong Presence

- Corporate headquarters located in Vancouver with R&D and manufacturing facilities
- R&D office and US manufacturing facilities in Bend, OR

## Strong Market Focus

- Fuel cell buses deployed in 6 transit systems
- 100+ fuel cell electric buses in service in the US
- Demonstration trucks at Port of Long Beach, Vancouver and in Alberta
- UPS class 7 demonstration trucks for California
- CP rail freight locomotive project

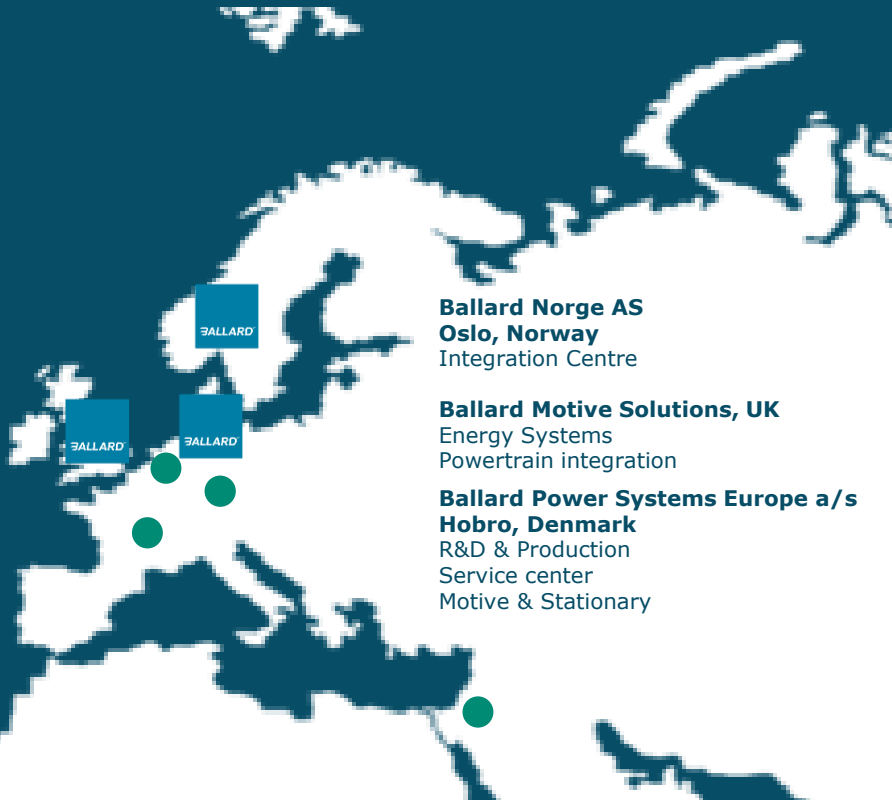
## Strong Support

- North American service and support, application engineering and training



# Ballard in Europe

Europe's leading fuel cell company



**Ballard Norge AS**  
**Oslo, Norway**  
Integration Centre

**Ballard Motive Solutions, UK**  
Energy Systems  
Powertrain integration

**Ballard Power Systems Europe a/s**  
**Hobro, Denmark**  
R&D & Production  
Service center  
Motive & Stationary

- **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
  - Local manufacturing of Ballard's fuel cell products for marine industry (FCwave™) and critical communication infrastructure (FCgen®-H2PM)
- **Ballard Motive Solutions Ltd** located in the UK
  - Ballard fuel cell powertrain Centre of Expertise
  - Hydrogen energy system integration and electromobility expertise
- **Strong Local Presence:**
  - 240+ employees in Europe dedicated to sales, market development, engineering, manufacturing, service, support and training
  - 200+ heavy duty vehicles in operation powered by Ballard
  - 3 rail projects
  - 6 marine projects
  - 500 power backup systems in service





# Ballard in China

Technology powering >30% of all fuel cell buses and trucks in China



Weifang, China  
Weichai Ballard JV  
Hy-Energy



Guangzhou, China  
Sales and Service Motive

## Strong Presence

- 2 operating platforms including wholly-owned China command center and one manufacturing joint venture, with over 350 staff

## Strong Market Focus

- Local manufacturing of FCvelocity<sup>®</sup>-9SSL, FCvelocity<sup>®</sup>-LCS fuel cell stacks, and FCmove<sup>™</sup> fuel cell modules
- Total production capacity for >40,000 fuel cell engines per year
- Development of next generation 'fit for market' products

## Strong Support

- Service support for world's largest commercially operating FC vehicle fleets (3,000 vehicles)
- Cooperation with over 20 local bus and truck OEMs on integration, application engineering, and training

