We Are Ballard Power Systems

We are Ballard Power making a meaningful difference with our fuel cell technology that will continue long into the future...

- 37 years of experience
- 21 years listed on NASDAQ
- 500 employees
- 2,000 patents/applications
- 250MW of fuel cell products shipped
- 2.4 million MEAs manufactured
- 3,000 stationary systems delivered
- 9 million kilometers in revenue service by fuel cell buses
- $80 million contract with VW/Audi
Ballard Power Products

- **Mission**: Meet customers’ power needs through delivery of high value, clean energy products that reduce customer costs and risks

**MARKETS**
- Transportation
- Portable
- Material Handling
- Telecom Backup

**PRODUCTS**
- Motive Modules: FCveloCity® Power Module (up to 200kW)
- Portable Systems: Squad Power Manager (SPM)
- Fuel Cell Stacks: Air-cooled FCgen®-1020ACS, Liquid cooled FCvelocity®-9SSL
- Stationary Systems: Hydrogen FCgen®-H2PM Systems
Ballard Technology Solutions

• **Mission**: to help customers solve difficult technical and business challenges in their PEM fuel cell programs through delivery of customized, bundled technology solutions.

• **Bundled solutions** featuring specialized technical expertise, a deep IP portfolio, and supply of technology to drive future opportunities
  
  o Integrated environment providing broad expertise, testing and manufacturing
  
  o Solutions to de-risk and accelerate fuel cell programs
  
  o Extensive intellectual property to solve technical challenges

Audi’s new H-tron Quattro concept vehicle uses technology and components developed with the engineering support of Ballard
Ballard offers flexible, scalable solutions for a wide range of motive application duty cycles and power requirements.
FCveloCity® Fuel Cell for Rail Applications
**Key Messages**

- **Electrification of the railway network is high on the agenda of the EU**
  - Currently, only 60% of the track in EU is electrified and it is much less in the East European member nations

- **Fuel cell technology is able to address powertrain electrification in the domains of rail propulsion, both for regional trains and shunt locomotives**

- **Electrification with fuel cells is an innovative and less capital intensive option than batteries**

- **Fuel cell powered shunt locomotives and trams have already been tested and demonstrated**
Fuel Cell Technology for Rail Propulsion

- Applications include shunting locomotives, trams, auxiliary power units and stationary railway signaling

- Elements of the value proposition:
  - Zero-emission operation
    - Reduces atmospheric greenhouse-gas emissions in urban centres and at railyards
    - Meets new emission regulations and goals
  - Quiet operation
    - Reduces noise pollution
    - Avoids citizens complaints due to noise of shunting operations
  - Improved infrastructure
    - No requirement for overhead catenary infrastructure
    - Central hydrogen refueling avoids cost of electricity-generation plant, transformers, and transmission lines

Fuel cell propulsion offers the environmental benefits of electric with the lower infrastructure cost of diesel
The FCveloCity® motive module product line is designed to meet all motive application power requirements from 30kW to 200kW.

### Product Series Table

<table>
<thead>
<tr>
<th>Product Series</th>
<th>FCveloCity®-MD</th>
<th>FCveloCity®-HD</th>
<th>FCveloCity®-XD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Power Levels</td>
<td>30kW</td>
<td>60kW, 85kW, 100kW</td>
<td>100kW, 200kW</td>
</tr>
<tr>
<td>Application</td>
<td>8 to 10 meter buses, battery hybrid range extenders</td>
<td>10 to 25 meter hybrid fuel cell buses</td>
<td>Rail and Marine</td>
</tr>
<tr>
<td>Availability</td>
<td>Available now</td>
<td>Available now</td>
<td>Available now / Under development</td>
</tr>
</tbody>
</table>

- Optimized for fuel cell hybrid drives
- Modular design
- High performance
- Easy installation/integration
- Safety features
- Cost reduction
Ballard FCveloCity® Motive Modules

- **Modular Design** to facilitate integration and enhance serviceability
- **High Temperature Operation** to improve overall vehicle fuel economy
- **Humidification** to maximize system performances and durability
- **Climate Protection** to ensure operation in extreme climates
- **High Pressure System** to prevent degradation and increase efficiency
- **Remote Diagnostics** for preventive maintenance
Ballard’s Market Leadership

• Over seven generations of heavy duty product development, Ballard has:
  o Partnered with over 10 bus manufacturers
  o Integrated 4 different drive systems
  o Powered more than 100 fuel cell buses in 20 cities
  o Driven over 9 million km across 12 countries with challenging climates and road conditions
  o Created 6 global service centers to ensure fleet availability
  o Achieved >20,000 hours of operation in London on a single fuel cell stack

We are very pleased with the performance of the fleet of fuel cell buses, as well as with the ongoing service and support that Ballard is providing.

– Mike Weston, Transport for London’s Director of Buses
Extending Ballard’s Market Leadership

52 buses are in revenue service today
+350 new fuel cell buses planned in the next 18 months

USA
- 12 in service
- 30+ planned

Europe
- 39 in service
- 30+ planned

Brazil
- 3 in service

China
- 300+ in service

India
- 1 in service
Fuel Cell Rail Projects
Ballard has participated in a number of rail fuel cell applications:

- **China**
  - 2 fuel cell trams under testing, 10 more planned to be integrated in 2016

- **USA**
  - 1st shunt locomotive delivered with 2 x P5 bus units to BNSF (240 kW net fuel cell)

- **South Africa**
  - 6 mine locomotives powered by FCvelocity-9SSL fuel cell stacks (17 kW gross fuel cell)

- **India**
  - 2 shunt locomotives fitted with 2 kW APUs
  - Another 20 APUs delivered and under integration
  - Indian Railway has issued a tender for 2 fuel cell powered shunt locomotives. Ballard expects to win the tender

- **Japan**
  - JR East integrated and evaluated a commuter train
Major Partners & Programs in China

Ballard has announced contracts with China bus and light rail OEM’s to produce fuel cell mass transit systems in large volumes.

<table>
<thead>
<tr>
<th>Active fuel cell buses</th>
<th>&lt;10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell buses in development</td>
<td>&gt;330</td>
</tr>
</tbody>
</table>

- **Nantong**
- **Foshan / Yunfu**
- **Yancheng**
- **Foshan**
- **Tangshan**

**Tram Projects**
Foshan-Yunfu
CRRC Qingdao Sifang / Gaoming District Tram Project

• World’s first commercial fuel cell tram line in Gaoming district of Foshan
  o 10 units of Ballard FCveloCity®-XD-200 modules to be delivered in 2016
  o Operations to begin late 2017 to early 2018
  o Preliminary specifications
    • Maximum speed = 70km/h
    • Refill time = 3 minutes
    • Range = 100km

CRRC Sifang – World’s first light rail tram, powered by a Ballard fuel cell module

Video of the tram
https://youtu.be/o9QAV_orYsc
• Customized fuel cell module for Ground Transport Vehicle prototype
• First successful demonstration in May 2016

CRRC TRC – World’s first tram to use a hybrid power system with fuel cells and supercapacitors, powered by a Ballard fuel cell module
## Light Rail Project Comparison

<table>
<thead>
<tr>
<th>Scope of Work</th>
<th>CRRC Qingdao Sifang</th>
<th>CRRC Tangshan Railway Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Develop 200 kW fuel cell system for rooftop light rail applications</td>
<td>• Develop 200 kW fuel cell system for rooftop light rail applications</td>
<td>• Meet rail-specific design standards supplied by customer</td>
</tr>
<tr>
<td>• • Meet rail-specific design standards supplied by customer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>CRRC Qingdao Sifang</th>
<th>CRRC Tangshan Railway Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 FC system for engineering testing at Qingdao, China</td>
<td>• 1 FC system for engineering testing in Tangshan, China</td>
<td>• 9 FC systems for revenue service in Foshan, China</td>
</tr>
<tr>
<td>• 9 FC systems for revenue service in Foshan, China</td>
<td>• Radiator(s) for FC system</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partners / Customers</th>
<th>CRRC Qingdao Sifang</th>
<th>CRRC Tangshan Railway Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CRRC Qingdao Sifang</td>
<td>• CRRC Qingdao Sifang</td>
<td>• Sinohytec</td>
</tr>
<tr>
<td>• Sinohytec</td>
<td>• Sinohytec</td>
<td>• City of Foshan</td>
</tr>
<tr>
<td>• City of Foshan</td>
<td>• City of Foshan</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Timing</th>
<th>CRRC Qingdao Sifang</th>
<th>CRRC Tangshan Railway Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• System 1 – May 2016</td>
<td>• System 1 – Jan 2017</td>
<td>• Systems 2-10 – Q4 2016</td>
</tr>
<tr>
<td>• Systems 2-10 – Q4 2016</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current Status</th>
<th>CRRC Qingdao Sifang</th>
<th>CRRC Tangshan Railway Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Assembled engineering prototype for internal testing</td>
<td>• Design in progress</td>
<td>• Planning EMC/EMI and IP testing</td>
</tr>
<tr>
<td>• Planning EMC/EMI and IP testing</td>
<td>• Preparing design review</td>
<td></td>
</tr>
</tbody>
</table>
Light Rail System Architecture

- 200kW fuel cell module for light rail applications under development
- Leverage common technology platform for two different architectures

CRRC Qingdao Sifang
- Single integrated systems (200 kW)
- Roof mountable enclosure
- Includes air filter in enclosure

CRRC Tangshan Railway Vehicle
- Two discrete integrated systems (100kW each)
- Roof mountable enclosure
- Includes DC/DC converter in each enclosure
# Ballard Rail Product Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>FCveloCity-XD200</th>
<th>FCveloCity-XD100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>V</td>
<td>412 – 635</td>
<td>750(^1)</td>
</tr>
<tr>
<td>Output Current</td>
<td>A</td>
<td>223</td>
<td>133(^1)</td>
</tr>
<tr>
<td>Rated Power</td>
<td>kW</td>
<td>200(^2)</td>
<td>100(^3)</td>
</tr>
<tr>
<td>Heat Rejection</td>
<td>kW</td>
<td>260</td>
<td>150</td>
</tr>
<tr>
<td>Dimensions</td>
<td>mm</td>
<td>1800 x 2000 x 550</td>
<td>1800 x 870 x 500</td>
</tr>
<tr>
<td>Net Dry Weight</td>
<td>kg</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Best Efficiency</td>
<td>%</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>IP Rating</td>
<td></td>
<td>IP56</td>
<td></td>
</tr>
<tr>
<td>Ambient</td>
<td>°C</td>
<td>-30 to 45</td>
<td></td>
</tr>
</tbody>
</table>

**Scope**
- Fuel Cell System
- Air Compressor
- Cooling Pump
- DC/DC Converter
- Radiator (Optional)

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\(^1\) Adjustable using DC/DC converter  
\(^2\) Net of air compressor, 24VDC loads  
\(^3\) Net of air compressor, 24VDC loads, DC/DC loss, radiator fan
Ballard rail products leverage automotive / bus technology and are currently designed for isolated-negative architecture

- **For 200kW system**
  - Tram employs conventional grounded negative system
  - Customer supplies galvanically – isolated DC/DC converter
  - Fuel cell system maintains isolated-negative
- **For 100kW**
  - Tram employs new isolated – negative architecture
  - Ballard supplies non-isolated DC/DC converter (smaller, less expensive, high efficiency)
  - Fuel Cell system maintains isolated-negative
- **Future Development**
  - Ballard system to be compatible with grounded-negative architecture
    - Either Ballard supplies isolated DC/DC or,
    - Fuel cell system inherently compliant with grounded-negative system
  - Tradeoff analysis results TBD
Fuel Cell Powered Shunt Locomotives
Rail Operating Conditions

- Lifetime of 30 years
- 19 hours per day 360 day per year
- Dynamic operation
- System installed on the roof
- Power requirement
- -15° to – 40°C operation
Typical Shunt Locomotive Layout
<table>
<thead>
<tr>
<th>Performance Aspect</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Power</td>
<td>300 – 500 kW</td>
</tr>
<tr>
<td>Mean observed power</td>
<td>85 – 150 kW</td>
</tr>
<tr>
<td>Mean fuel usage</td>
<td>5.6 to 8 kg per hour</td>
</tr>
<tr>
<td>On board H2 storage</td>
<td>60 kg at 350 bar</td>
</tr>
<tr>
<td>Mean power plant efficiency</td>
<td>52%</td>
</tr>
</tbody>
</table>
Duty Cycle: Example shunt locomotive duty cycle. Computed 75 kW mean power is based on a 20-h operating shift.
## Key Rail Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN61373</td>
<td>Railway application – Rolling stock equipment – Shock and vibration tests</td>
</tr>
<tr>
<td>EN50121-3-2</td>
<td>Railway application – Electromagnetic compatibility - Part 3 - 2:Rolling stock - Apparatus</td>
</tr>
<tr>
<td>DIN5510-2</td>
<td>Preventive fire protection in railway vehicles</td>
</tr>
<tr>
<td>IEC60529</td>
<td>Degrees of protection provided by enclosures (IP code)</td>
</tr>
<tr>
<td>IEC60077</td>
<td>Railway applications - Electric equipment for rolling stock</td>
</tr>
</tbody>
</table>

- **Additional standards are being evaluated**
Funding Opportunities

- FCH:JU funding
- Connecting Europe Facility (CEF) under DG Move
- Shift2Rail
**Summary**

- Ballard will provide the engineering resources to help integrate fuel cell and associated system into shunt locomotive platforms.
- Ballard will meet the rail safety & certification standards.
- Full lifetime support for the fuel cell systems will be offered.
- Ballard FCveloCity® heavy duty power modules continue to lead the industry in performance, durability, cost, and overall road experience.

<table>
<thead>
<tr>
<th>Flexible Platform</th>
<th>Proven Durability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Leadership</td>
<td>High Performance</td>
</tr>
<tr>
<td>Manufacturing Expertise</td>
<td>Tier 1 Customers</td>
</tr>
</tbody>
</table>
Thank you

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