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Hydrail: Moving Passengers Today and Freight Tomorrow

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On a clear day you can see the future

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Alstom’s Coradia iLint—world’s first hydrogen train now in service

China Railway Rolling Stock Corp (CRRC) Hydrail Trams

Commuter Hydrail Retrofit in the UK

United Kingdom

Breeze Converted Class 321 Trains

The Business Case for Zero-Emission Passenger Hydrail based on the combined Rolling Stock and Energy Infrastructure TCO

Diesel MU

Diesel Fueling Infrastructure

Mature Energy Supply Chain
Operator Storage and Dispensing

Electric MU

Overhead Catenary System

Operator builds entire system—catenary wires, traction power system and grid interconnection

Hydrogen MU

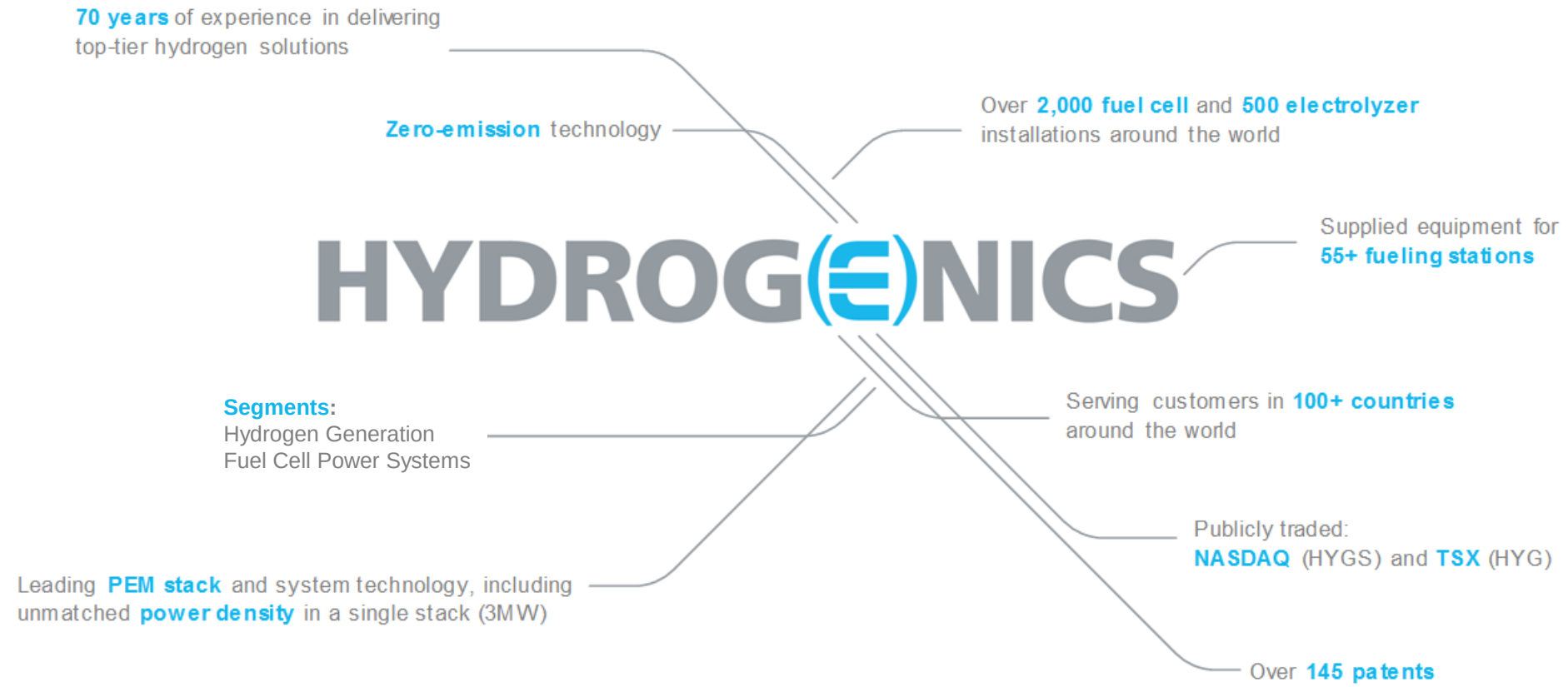
Hydrogen Fueling Infrastructure

Build-out H2 Prod'n and Distribution
Operator Onsite Hydrogen Storage and Dispensing

Passenger Hydrail vs. OCS Electric

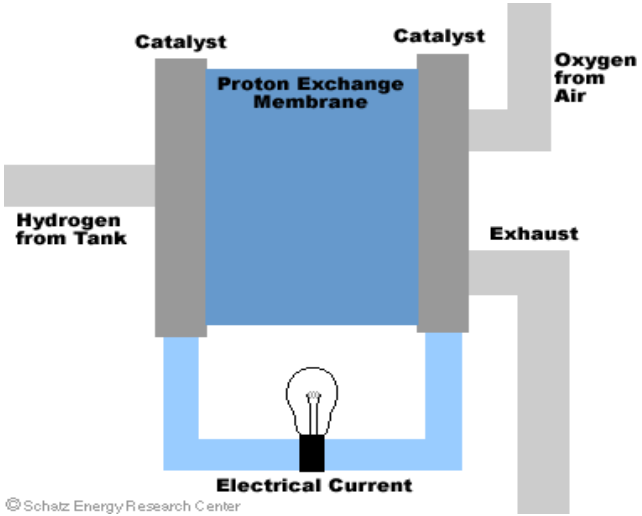
- Lower upfront Capex and lower TCO over time
- Avoids roadwork disruptions and utility relocates for faster implementation and revenue capture
- Greater operational flexibility by providing service on both diesel and electrified lines
- Scalable solution as capacity can be added to meet ridership growth over time
- Avoids negative aesthetics and visual impact of overhead wires in urban areas
- Hydrail rolling stock costs and fueling infrastructure will decrease dramatically over next decade

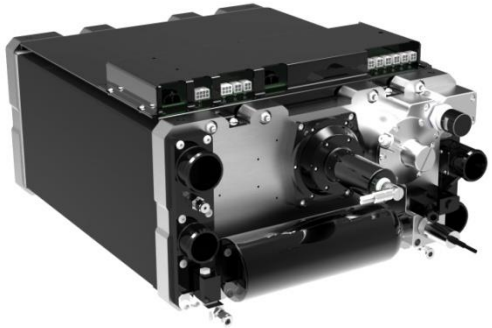
Global Leader in Hydrogen Technology



Hydrogenics PEM Fuel Cell Module

Fuel cells use hydrogen to create electricity for **mobility** and **critical power applications**





1 Fully Integrated Systems

Integrated software and mechanical control

2 Differentiated Technology

Self-humidified, low-pressure stack

3 High Reliability

Unlimited start/stop, sub-zero operation

4 Flexible Architecture

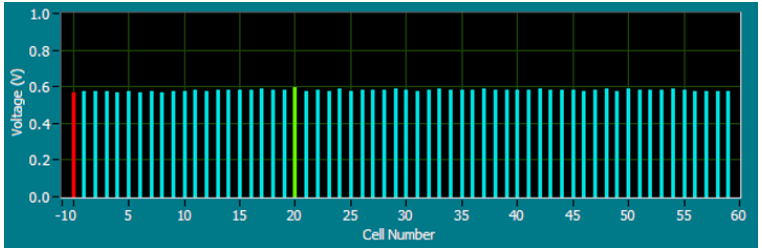
Scalable stack for mobility and stationary applications

Safety & Predictive Maintenance

- Design based on FMEA (Failure Mode and Effects Analysis)
- Multi-function stack end plate
- Integrated manifold
- Hardware safety
  - Temperature, Pressure connect to the H2 inlet solenoid
- Predictive maintenance and improved system availability
- Advanced onboard controls and diagnostics
  - Self-check can give a stack health report after each run
- Shock & vibration system tolerance

Multi-function stack end plate

Fuel delivery assembly



Cell voltage graph

Fuel Cell Power Modules for Mobility Applications

30 kW

- PEM FC Power Module
- Fundamental Building Block
- Freeze-protected
- Integral Balance of Plant
- Ease of Integration

60 kW

- CELERITY designed for heavy duty; ready connection with Siemens ELFA electric drive
- Full feature set, including Pre-charge, Load contactor, reverse current protection, IP rated enclosure

120+ kW

- Multiple HD30 FC modules plus:
- Frame and enclosure
- Manifolding
- Single interface set
- 120/150/180/240kW+ variants

Powering Planes, Trains, and Buses and Trucks

Germany

Germany

USA

China

USA

Switzerland

Coradia iLint HyPM™ Design and Delivery Schedule

Date	Design and Delivery Schedule:
2014-09	LOI signed by 4 German States
2015-09	1st Prototype FC System delivered
2016-09	Unveiling at Innotrans Exhibition, Berlin
2017-03	1st two Pre-Series trains on track testing
2018-1H	Completion of Type Approval testing
2018-2H	Pre-series validation in revenue service

Fuel cell production and testing for Alstom's Coradia iLint

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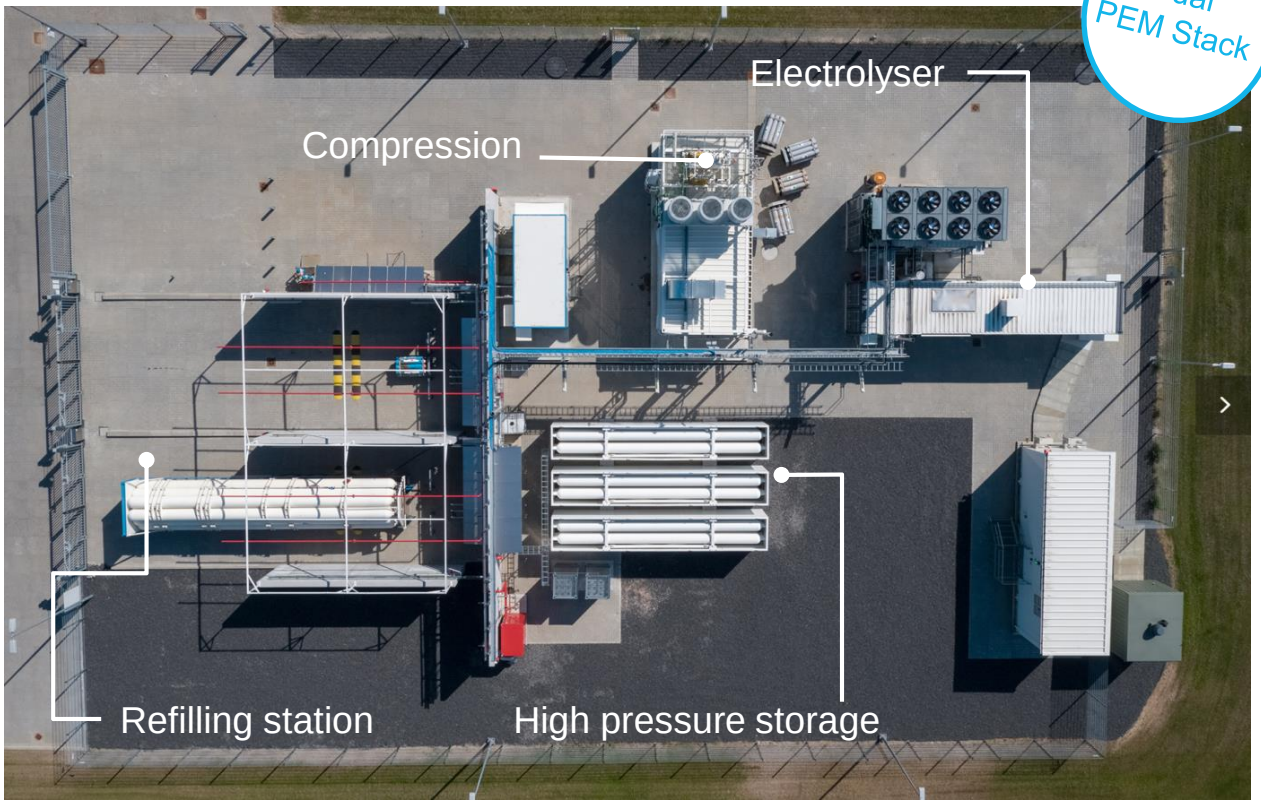
HyBalance Facility, Denmark
Producing hydrogen for refueling stations and industrial customers



Air Liquide

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Markham Energy Storage Facility, Ontario
Grid Balancing Services for IESO

5 MW Plant Architecture

ENBRIDGE

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What's Holding Us Back for Commuter Hydrail?

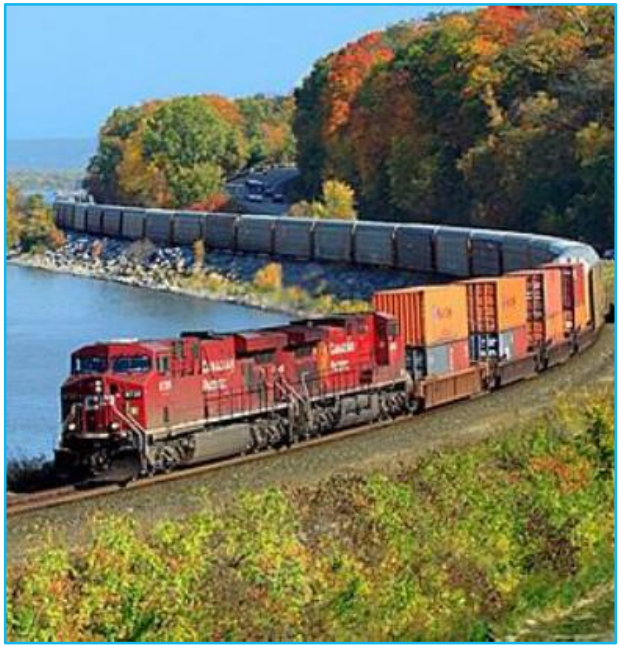
- Industry is ready for commercial deployments for hydrogen rolling stock
  - Fuel Cell companies have been working directly with the rolling stock suppliers to develop the design and integration for several years now
  - Demonstration trials underway have validated design and performance characteristics
- Scaling of hydrogen fueling infrastructure capacity
  - Hydrogen production and distribution scale exists for refineries today
  - Electrolysis is established technology, but larger scale plants required for Hydrail
  - Required fueling dispensing volumetric and transfer rates are achievable with today's engineering capabilities
- Volume production
  - No technology limiting barriers, but component supply chain is immature today
  - Volume production needed to accelerate cost reductions over next decade
- Project financing and structures
  - Railway operators accustomed to 30+ year asset planning horizon and life
  - New hydrogen technology has higher risk than century old Overhead Catenary System

What about Hydrail Freight Trains?

Commuter Hydrail		Freight Hydrail	
✓	Rolling Stock	✓	• No technical issue for FC electric power on Class I Locomotive
✓	Shorter Operating Range	✗	• Long haul freight routes
✓	On-board Gaseous Fuel Storage	✗	• Gaseous hydrogen not feasible
✓	Overnight Fleet Stabling	✗	• North America wide operator logistics
✓	Centralized Depot Refueling	✗	• Massive investment for hydrogen fueling infrastructure network required

Freight Hydrail Research Needs

- Operating range and hydrogen fueling infrastructure are constraints today
- On-board liquid hydrogen is feasible option as it would provide sufficient energy density for long-haul freight trains, but massive fueling infrastructure investment to support North American network
- Other fuel options are on-board liquid at ambient
  - Methanol
  - LOHC
  - Ammonia
- Let's not lose sight of the H2@Scale end goal



Courtesy photo from
http://transportationcommunicationcanada.weebly.com/references.html

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