HYDROGENICS

PEM Fuel Cell Power Modules, Systems, and Applications

Changing power
...Powering change

CARB Zero Emission Vehicle Symposium
Sacramento, California
Sept 25-27, 2006

Agenda

- Introduction to Hydrogenics
- Fuel Cell Power Modules and Systems
- Fuel Cell (Hybrid) Applications
- Closing Remarks

Company Profile

- **Established in 1995**
- **Three business units**
  - OnSite Generation
  - Power Systems
  - Test Systems
- **Global Presence**
  - Canada: Toronto & Vancouver
  - Belgium
  - Germany
  - Japan
  - USA
- **Listed on NASDAQ (HYGS) & TSX (HYG)**
- **300 employees**
- **87 patents awarded; 550 pending**

Business Units and Markets

OnSite Generation

- Industrial Hydrogen
- Refueling Stations

Power Systems

- Backup Power
- Mobility

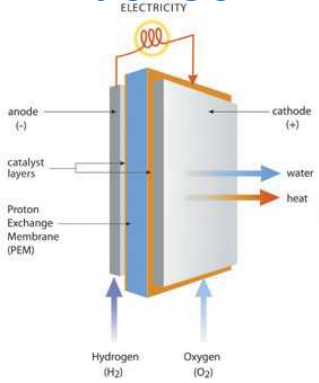
Test Systems

- Test Stations
- Diagnostics
- Test Services

Fuel Cell Power Products

Core competency from PEM fuel cell to complete solutions:

The PEM Fuel Cell



- Single cell by-products are heat and water

The Fuel Cell Stack

- Multiple cells layered to create a stack

The Fuel Cell Power Module

- Heat and water management
- Gas humidification
- Software & hardware controls
- Power conditioning
- Fuel management

The Fuel Cell Power Pack

- Power Module
- Electrical Storage Device
- Hybrid control hardware & software
- Thermal mgmt.
- H_2 storage

HyPM® Standard Fuel Cell Products

Range of Fuel Cell Power Products targeting specific needs

- Fuel Cell Power Modules for OEMs and SIs- 8, 12, 16, 65 kW
- DC Power Solutions – Fuel cell power module integrated with power conditioning packages to deliver specific nominal voltages - 24, 36, 48, 72 Volts, suited to diverse end user needs
- Fully integrated Fuel Cell Power Packs consisting of fuel cell power module, thermal management, power conditioning, energy and hydrogen storage for end user applications

HyPM® Fuel Cell Power Module Technology

End Plate

MEA (Membrane Electrolyte Assembly)

Flowfield Plate

Humidification

Air delivery

Fuel delivery

Coolant Pump

Air Flow Meter

Controls

Air Filter

FC Stack Subsystems

FC Power Module Subsystems

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HyPM Fuel Cell Power Pack

Fully Integrated Solutions Fits Existing Battery Compartment

Electrical and H_2 Storage

HyPM Power Module

Thermal Management

Power Conditioning

Fuel Cell Applications – Back-Up Power and APUs

Fuel Cell Applications – Light and Off-Road Mobility

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Fuel Cell Applications – Medium and Heavy Mobility

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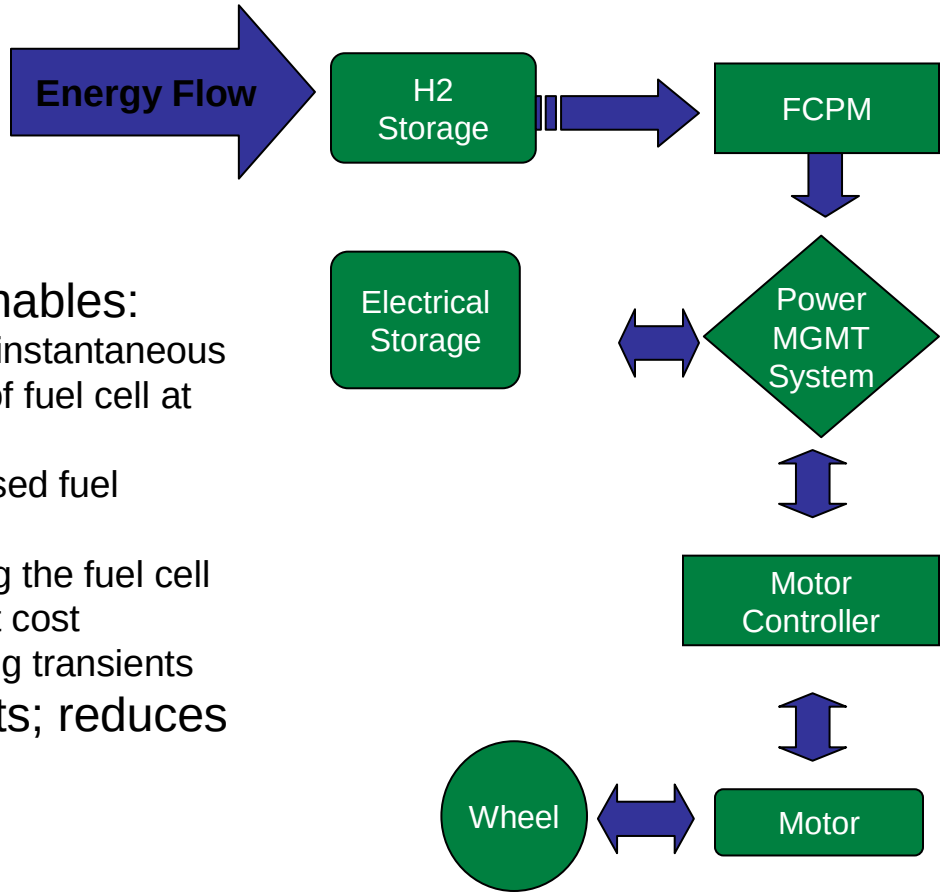
Fuel Cell – Electric Hybrid Benefits

- Hybrid combines Fuel Cell with Electrical Storage Device:
  - Ultracapacitors
  - Batteries
  - Flywheel
- Modes of operation:
  - Acceleration
  - Steady State
  - Braking
- Electrical Storage Device enables:
  - Improved system performance (instantaneous power response and operation of fuel cell at optimal efficiency range)
  - Regenerative braking for increased fuel efficiency
  - reduces system cost by reducing the fuel cell size; reduces stack replacement cost
  - Increases durability by smoothing transients
- Reduces Development Costs; reduces time to commercialize

Fuel Cell – Electric Serial Hybrid Vehicle Power Train



HyPM Fuel Cell Power Pack

Application: Class 1 Lift Trucks

- Operating voltage is 48 VDC
- 1.6 kg of hydrogen at 350 bar (5000 psi) – enough fuel for an entire shift
- 10 second cold start
- Instantaneous warm start
- Refuel in under 2 minutes

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Fuel Cell Powered Lift Truck

Power Train Specifications

Configuration	Fuel cell-ultracapacitor electric hybrid
Fuel Cell Power Module	12 kW
Peak Power (10seconds)	27 kW
Hydrogen Storage	1.6 kg @ 350 bar

Vehicle Specifications

Lift Truck Type	Hyster E55 Class 1 Lift Truck
Lifting Capacity	2300kg (5000lb)
Wheels	Four (4)
Tire Type	Cushion Tire

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Benefits of Fuel Cell Power Packs in Lift Trucks

- Releases No Harmful Emissions
- Increases Productivity:
  - Enables fast refueling <5 minutes
  - Provides consistent, abundant power
  - Offers extended run (1.7 shifts per fill – in an 8-hour shift)

Levels of Hybridity

Vehicle Examples	Fuel Cell Pwr / Motor Cont Rated Pwr	Fuel Cell Power as a Percentage of Motor Power	Hydrogen (kWh_e) as a Percentage of Total kWh_e cap.
	20 / 120	17%	78%
	32 / 123	26%	79%
	12 / 25	48%	91%
	180 / 170	100%+	97%

Fuel Cell Hybrid Midi Bus

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Fuel Cell Hybrid Midi Bus

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Overview

Technical Data

Length	5.3 m (17 ft)
Type	Low floor
Seats	8
Max speed	33 km/h (20 mph)
Autonomy	200 km (125 mi)
Drive	12 kW PEM Fuel Cell
Motor	25 kW
Fuel	Hydrogen
Hydrogen storage	5.8 kg @ 2850 psi
Energy storage	NiCd Batteries

Fuel Cell Hybrid Midi Bus

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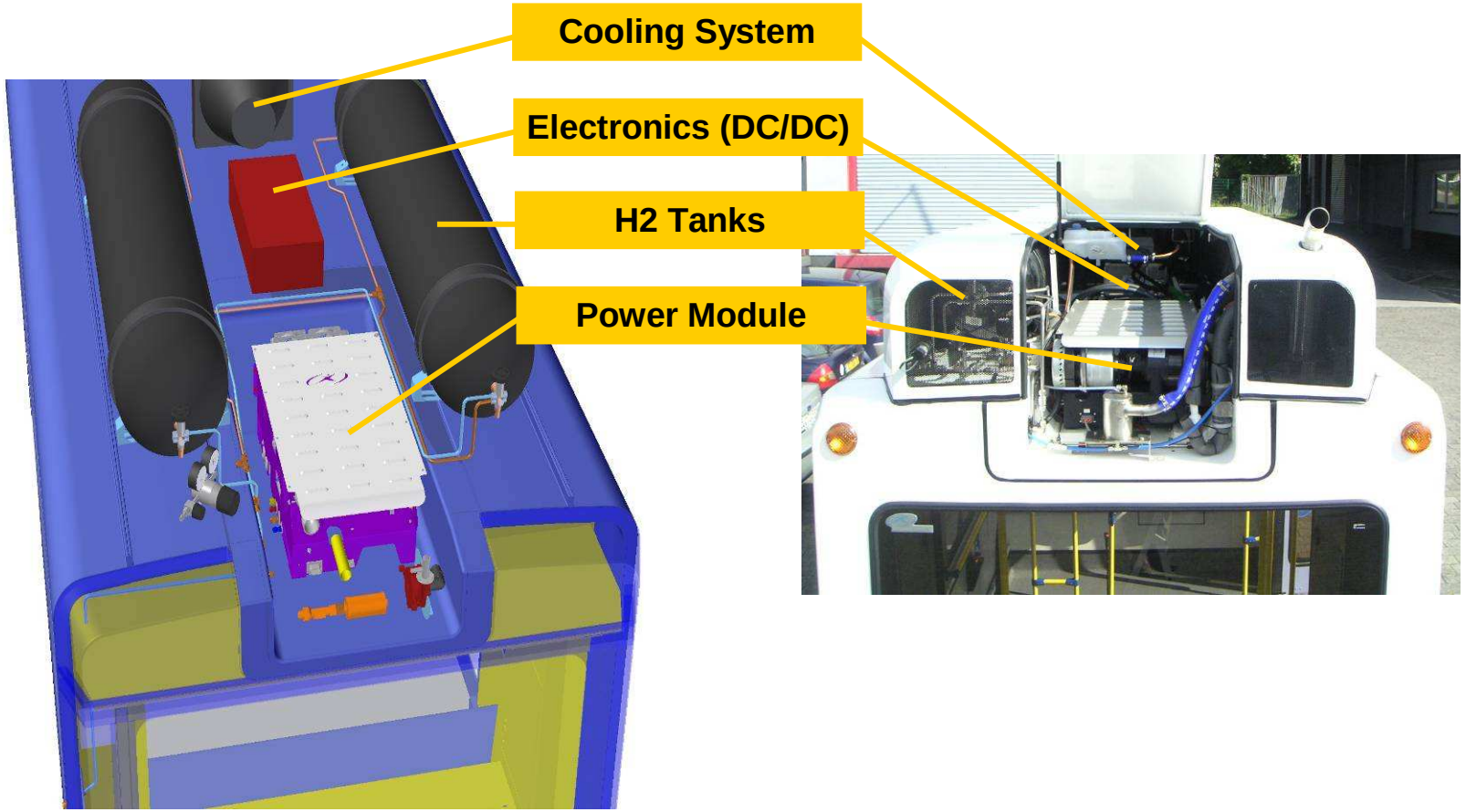
Location of Main Components



Planning

Execution

Fuel Cell Hybrid Midi Bus

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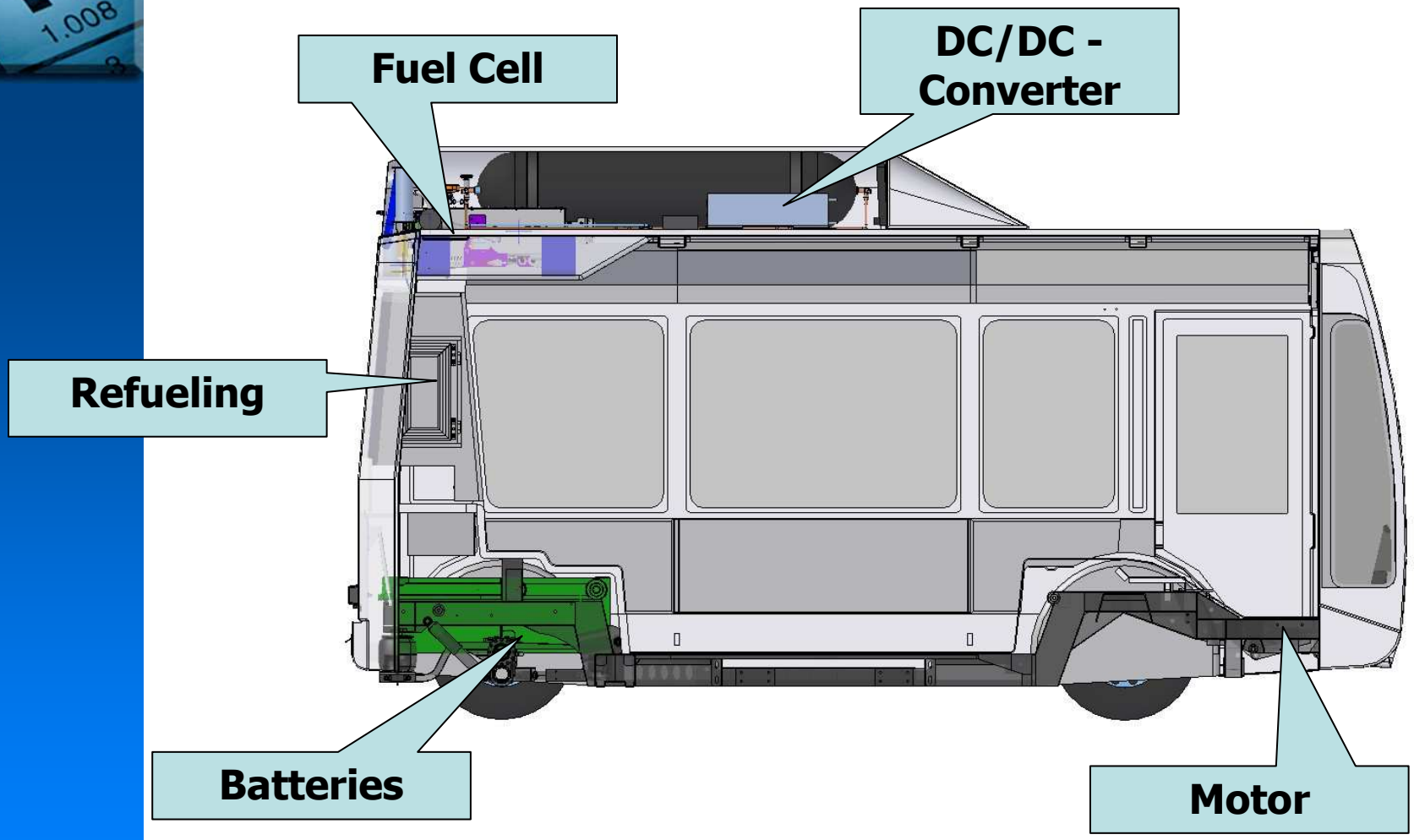
Location of Main Components



Hickam AFB Fuel Cell Bus

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Hickam AFB Fuel Cell Bus

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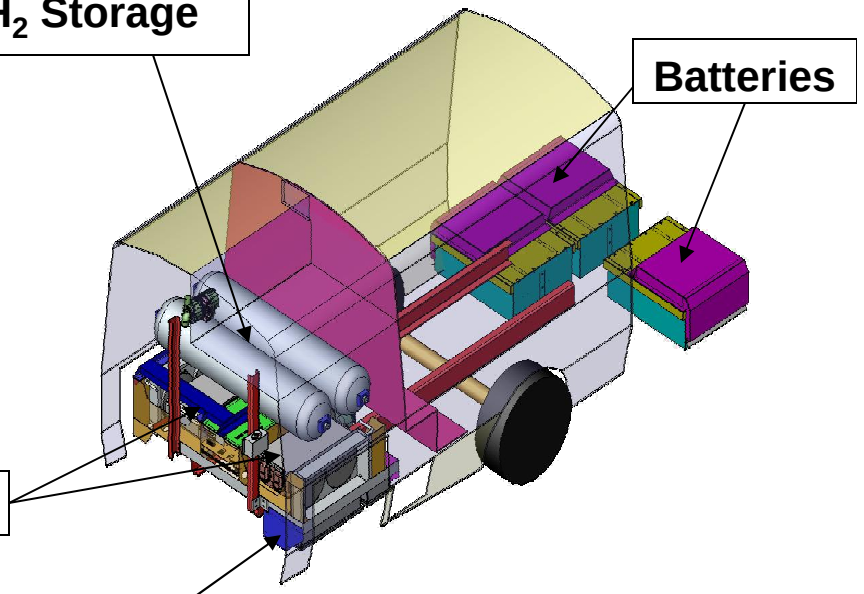
Technical Data

Length	30 ft (9.4 m)
Type	High floor
Seats	23
Max speed	60 mph (100 km/h)
Autonomy	125 mi (200 km)
Drive	20 kW PEM Fuel Cell
Motor	120 kW
Fuel	Hydrogen
Hydrogen storage	10 kg @ 350 bar
Energy storage	Lead Acid Batteries



Closing Remarks

- It is important how the fuel cell stack is treated, therefore it is important how the balance of plant and system components are chosen/designed and system integrated.
- Fuel Cell technology is ready for early deployment in certain stationary and mobility markets
  - Backup Power
  - Forklift Trucks
  - Hybrid Buses
- Fuel Cell mobility solutions are better if combined with energy storage
- Hybrid solutions will accelerate the commercialization of fuel cell technology
- Consider battery dominant, fuel cell, plug-in hybrid systems as a new viable powertrain architecture

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Thank you!

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