

Hydrogenics Corporation
MDEC October 2004

HYDROGENICS  clean efficient
quiet versatile



Fuel Cell Hybrid
Light Duty Mining Vehicle

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clean

Agenda

1. Introduction to Hydrogenics
2. Fuel Cell Basics and Benefits
3. State of Fuel Cell Technology
4. The Hybrid Influence
5. Market Development Timeframe
6. H₂ Refueling
7. Early Deployments




AGENDA

- Intro
- Fuel Cell Basics & Benefits
- State of Tech.
- Hybrid Influence
- Market Dev't.
- H₂ Refueling
- Early Deployments
- Mobile Generation


HYDROGENICS 

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Hydrogenics Overview


- Toronto-based developer of PEM fuel cell systems and hydrogen generation/refueling systems
- Focused on design and rapid prototyping of fuel cell power modules (engines)
- Working with world-leading OEMs incl. GM, John Deere and ChevronTexaco
- World leader in fuel cell R&D equipment (operating as Greenlight Power Technologies)
- Public company listed on NASDAQ: HYGS and TSX: HYG
- 200+ employees worldwide including Mississauga headquarters, Burnaby, B.C. (Greenlight), and satellite operations in Germany and Japan

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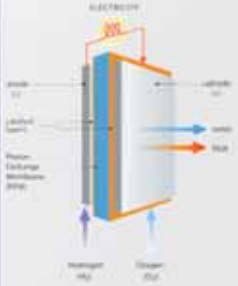
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Fuel Cell Power basics:

From Cells to stacks to power modules


The PEM Fuel Cell → **The Fuel Cell Stack** → **The Fuel Cell Power Module**



H2 and O2 inputs
Single cell provides ~ 0.7V
Only emission is heat and water




Multiple cells layered to create a stack



- Heat and water mgmt
- Gas humidification
- S/W and H/W controls and diagnostics
- Power conditioning
- Fuel mgmt


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Value propositions for Fuel Cells

Operational benefits include:

- High quality, reliable power
- Increased power generating efficiency (50%+)
- No harmful GHG emissions at point of operation
 - (e.g. CO, CO₂, NO_x, SO_x)
- Reduced noise emissions
- Reduced operating and maintenance costs
- Design freedoms around electrification
 - Integration of more efficient electric drives
 - Powering navigation, wireless fleet mgmt and other electronic equipment
 - Supply off-board power
 - Ergonomic freedom around distributed electric drive components
 - Reduction in injuries and damage
→ Productivity increase

Adoption driven by end-users valuing the benefits fuel cells provide⁵

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Fuel Cell technology is ready for early markets

Hydrogenics' HyPM Platform

- Broad Range of Products: 6, 10, 20, 65 kW
- Demonstrated Durability: 4000 hrs plus
- Start-stop cycles without degradation: 5000
- High Efficiency: 56 – 48% LHV
- Compact: 156L for HyPM 10 (16L/kW)
- Weight: 88kg for HyPM 10
- Low Pressure System: <20kPa
- CANBus Communication System
- Voltage Input for Startup: 12V
- Sub-zero operation solutions under test

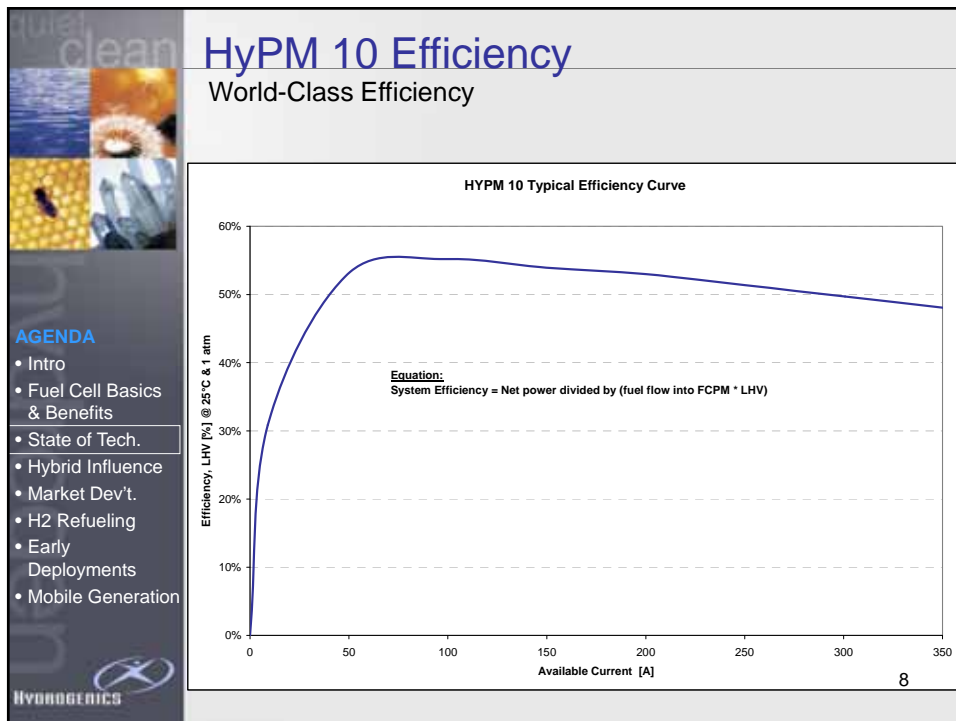
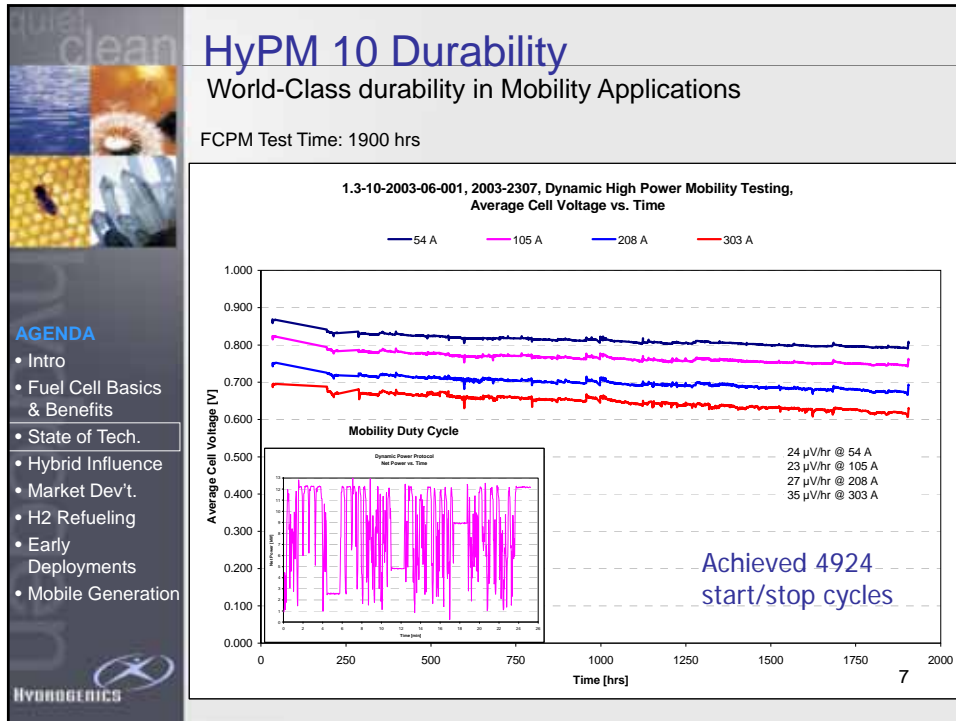


HyPM 10



HyPM 20

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Fuel Cell – Electric Hybrids

unleash additional benefits

Fuel Cell – Electric Serial Hybrid Vehicle Power Train

- **Hybrid combines Fuel Cell with Electrical Storage Device:**
 - Ultracapacitors
 - Batteries
- **Modes of operation:**
 1. Acceleration
 2. Steady State
 3. 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
 - Peak shaving:
 - reduces system cost by reducing the fuel cell size,
 - Increases durability by smoothing transients


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Fuel Cell/Ultracapacitor Hybrid Test Vehicle

Vehicle Test Data


- Average FC power - 2.5KW
- High peak power/average power ratio – 8 (16 KW peak)
- Using HyPM 6 and 90F of ultracapacitors

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I.C.E. Hybrids can enable Fuel Cell Adoption


- **Internal Combustion Engine (I.C.E.) Hybrid demand and production is growing**
 - Toyota Prius, Honda Insight and Civic, and Ford Escape
- **I.C.E. Hybrid adoption will develop:**
 - Electric power train technology and supply chain
 - Electric power train service & support network, including emergency services
 - Required electric vehicle codes and standards
 - Raising public awareness and comfort with hybrid electric vehicles
- **Potential to accelerate Fuel Cell Hybrid adoption in industrial vehicle applications requiring low noise and/or zero emissions**

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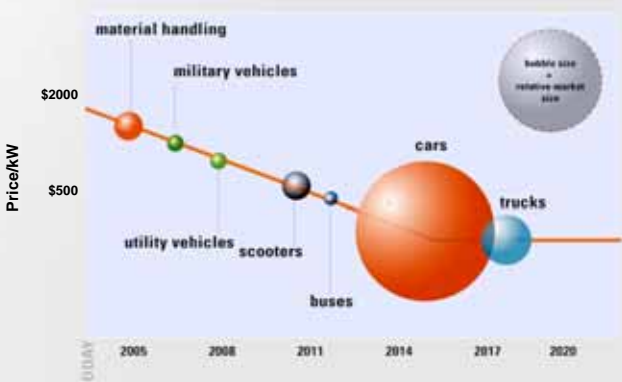
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Fuel Cell Adoption:

Industrial applications poised to precede automotive applications



Adoption in off-road markets driven by:

- Centralized refueling for captive fleets
- Increased efficiency, reduced noise emissions
- No harmful emissions (e.g. CO, CO₂, NO_x, SO_x)
- Reduced operating and maintenance costs
- Design freedoms around electrification

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Industrial vehicles dominate Mobility Applications

(19 of 25+ deployments)

Select Industrial Vehicle FC applications include:

- 1. Material Handling**
 - Two NMHG 4-wheel rider trucks (5000lbs)
 - General Hydrogen (HyPM 10s)
- 2. Commercial Work, Grounds Equipment and Mining Vehicles**
 - 2 generations of Fuel Cell Powered Gators with Deere (HyPM 10 and 20s)
 - Toro Turf Equipment Application
 - CANMet Light Duty Mining Vehicle (HyPM 10)
- 3. Military and Ground Support Vehicles**
 - CTC Ground Support Pullback Tug (HyPM 65)
 - QTWW Light Duty Military Vehicle (HyPM 10)




FC Forklift demo with NACCO



FC CWV demos with Deere

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Case Study:

NMHG Class 1 Forklifts

- Developed fuel cell hybrid power solution to replace battery pack in Hyster™ Class 1 5000lbs forklift
 - Fits within existing battery space (48V – 850Ah)
 - HyPM 10
 - Ultracapacitor hybrid system
 - Thermal MGMT
 - H2 storage
 - Refueling time of <2 minutes
 - 8 hour shift per fill
 - Regen capable
- 2 forklifts to be deployed at GM Oshawa automotive assembly plant and FedEx ramp
- Project partners include NMHG, Deere, GM, FedEx

Hydrogenics will rely on its experience with the SDTC forklifts to assure a vehicle, fueling system package and with the training and service lessons that will be gained from their deployment at GM, FedEx, and Deere.





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Case Study:
Light Duty Mine Vehicle project overview

- Proposal with Canadian Transportation Fuel Cell Alliance (CTFCA)
- Project focuses on the demonstration of a fuel cell power light duty vehicle and electrolyzer refueler in real world application
- Fuel cell hybrid power solution will replace the 16 kW diesel engine in a John Deere Gator
- Gator will be deployed at the CANMET-MMSL facilities in Val d'Or, Quebec
- Project partners include John Deere, HATCH, CANMET-MMSL and CTFCA

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Case Study:
Light Duty Mine Vehicle project overview


Rationale

- Emissions from diesel-powered underground vehicles present serious environmental, health and safety, and productivity issues
- Approximately 3,500 diesel powered units are at work in the Canadian underground metal mines
 - Almost half are light duty service vehicles
- Highly mechanized underground mines grow in number and depth, relying more and more on specialized light duty service vehicles
- Light duty vehicles require less financial and design resources to convert to fuel cell power than heavy duty vehicles :
 - Less stringent duty cycles
 - Much lower peak power requirements
 - Greater off the shelf electrical component availability
- Development of light duty applications is an excellent first step towards larger scale hydrogen power deployment in underground mining applications




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Case Study:
Light Duty Mine Vehicle project overview

Phases of Work

- **Phase 1: Vehicle Energy Requirements (Duty Cycle) and Environment Assessment**

 - To ensure the vehicle peak power and mean power requirements are met, the duty cycle of an internal combustion engine worksite vehicle will be assessed at the CANMET experimental mine
- **Phase 2: Vehicle and Refueling Unit Design and Development**
- **Phase 3: Vehicle Performance Tests and Demonstration**

 - Mine site vehicle demonstration and performance evaluation sessions will be conducted to validate the technology's viability in the underground environment
 - Two production weeks in two different mines shall be used to test the fuel cell powered vehicle and the refueling unit



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Case Study:
Light Duty Mine Vehicle project overview

Roles and Responsibilities


- **Phase 1: Vehicle Energy Requirements (Duty Cycle) and Environment Assessment**

 - CANMET-MMSL personnel will conduct the preliminary assessment of the unit for underground mine utilization
 - Vehicle will be tested at CANMET-MMSL's site at Val-d'Or, Quebec
- **Phase 2: Vehicle and Refuelling Unit Design and Development**

 - John Deere and Hydrogenics will collaborate on the design to assure that performance, durability, and safety requirements are in accordance with the specification established in phase I
 - The hydrogen storage supplier will design an on-board 1 – 2 kg **usable hydrogen vessel**
- **Phase 3: Vehicle Performance Tests and Demonstration**


 - Hydrogenics and John Deere will perform validation tests on the vehicle to assure that performance and safety specifications are met before it is released to CAMET
 - CANMET-MMSL will ensure proper data monitoring and vehicle refueling

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On-Site H₂ Generation

eliminates distribution obstacles


- 3 options for sourcing H2 fuel:
 - Delivered H2
 - Onsite Electrolysis
 - Onsite Reformation
- Hydrogenics is developing on-site H2 generation products based on PEM Electrolysis and Natural Gas Reformation
 - Enablers to mobility fleets
- Electrolysis enables use of renewable energy sources
- Hydrogenics recently unveiled Toronto's first H2 Refueling Station at ExPlace using renewable energy from TREC Wind Turbine



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Early Fuel Cell deployments

require integrated approach

- Hydrogenics has executed early demonstrations and deployments by developing and offering:
 - Fuel Cell Power Module products in the 5, 10, 20 and 65 kW range
 - Duty cycle analysis and system modeling
 - Hybrid power solutions with ultracapacitors and/or batteries
 - System integration and engineering support
 - H2 refueling companion products
- Hydrogenics enables evaluation of the technology and market potential for all partners






Summary

- Fuel Cell technology is ready for early deployment
- Fuel Cell mobility solutions are predominantly hybrid configurations
- Industrial and Off-Road applications likely to precede automotive
- I.C.E. Hybrids facilitate and accelerate Fuel Cell adoption in Industrial Vehicle applications

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