



## PEM Fuel Cell Early Market:

Material Handling Equipment



Changing power  
...Powering change

NHA Fall 2007 Topical Forum  
Hydrogen Uses in the Military

October 3, 2007

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## Hydrogenics Profile



- Three business units
  - OnSite Generation
  - Power Systems
  - Test Systems
- Leading global provider of hydrogen infrastructure solutions
- Delivering 'leading edge' fuel cell products to world class OEMs and system integrators
- World leader in fuel cell test systems
- 1,600+ hydrogen products deployed worldwide since 1948
- 84 patents held and 459 patents filed
- Headquartered in Toronto, Canada - approximately 250 employees worldwide



NASDAQ: HYGS TSX: HYG



Head Office - Toronto, Canada

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## Hydrogenics Fuel Cell Power Modules in Military Applications



Fuel cell hybrid step van,  
Hickam AFB, Honolulu, HI  
Source: Hydrogenics  
Corporation



Fuel cell hybrid aircraft  
tow tractor, Hickam AFB,  
Honolulu, HI  
Source: Presentation by  
the Hawaii Center for  
Advanced Transportation  
Technologies



Fuel cell plug-in hybrid bus,  
Hickam AFB, Honolulu, HI  
Source: Hydrogenics Corporation



Fuel cell powered off-road vehicle  
Source: Quantum Technologies website



Regenerative fuel cell system auxiliary  
power unit for military vehicles  
Source: Hydrogenics Corporation



Fuel cell system auxiliary  
power unit for military  
vehicles  
Source: Hydrogenics  
Corporation

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## Forklifts Accelerates Commercialization of Fuel Cells in Other Applications



Fuel cell deployment in the forklift market provides an accelerated path for fuel cell technology deployment in cars and trucks by:

- developing the supply chain
- increasing durability and reliability through lessons learned in the field
- increasing customer comfort with the technology and hydrogen fuel
- increasing volumes
- decreasing cost

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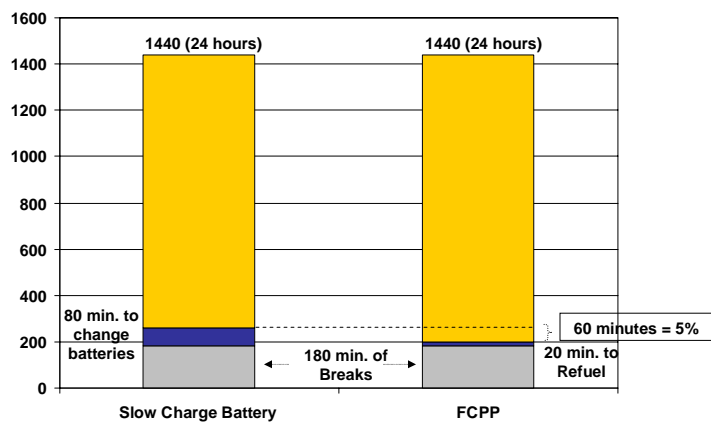
## Unleashing Productivity in Industrial Trucks

HyPM Fuel Cell Power Pack is a clean power solution that:

- Releases no harmful emissions
- Increases lift truck uptime through:
  - Reduced refueling time
  - Extended run-time between fills
  - Providing consistent and abundant power
- Fits within the existing battery compartment



## FCPP Increases Uptime by 5%



5% Productivity Increase Can Reduce Fleet by 1 in 20

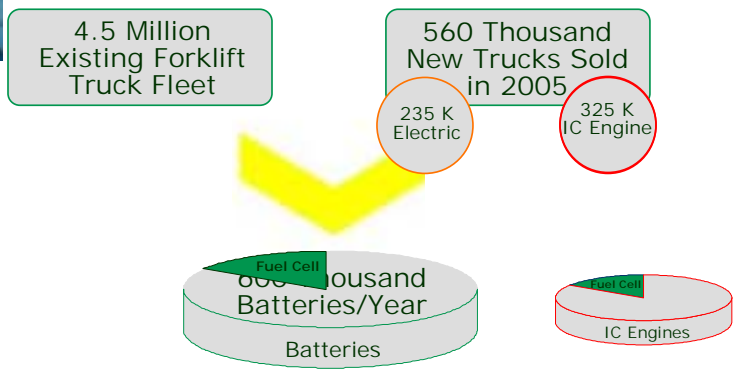


## “Best of Both Worlds”

FCPPs Combine Benefits of ICEs and Batteries to Meet Increasingly Stringent Air Quality Regulations

		Batteries	ICEs	Fuel Cells
<b>Emissions</b>	Zero Emissions	✓		✓ H <sub>2</sub> O
<b>Productivity</b>	Extended Runtime		✓	✓ >10 hours
	Fast Refueling		✓	✓ <5 minutes
	Abundant Power		✓	✓
<b>Operational Efficiency</b>	Compact Refueler		✓	✓ > 20 trucks/dispenser
	Unstaffed Refueler		✓	✓

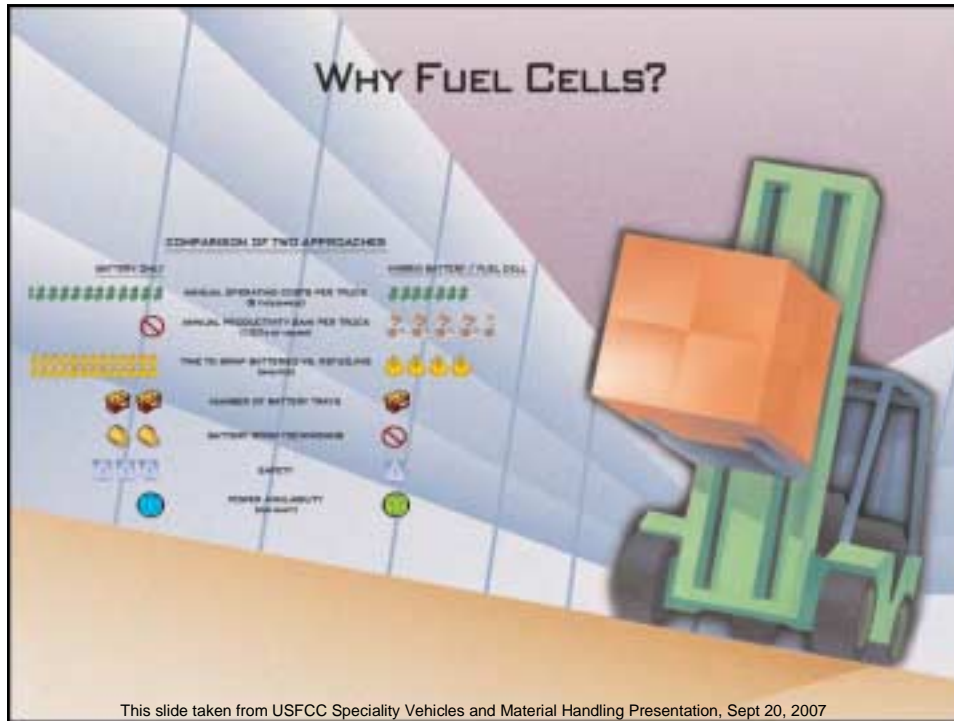
## Material Handling Market Size




### Goals

- 1) Capture High Productivity Users' Business
- 2) Accelerate Internal Combustion to Electric Conversion


This slide taken from USFCC Specialty Vehicles and Material Handling Presentation, Sept 20, 2007





## Key Parameters and Results

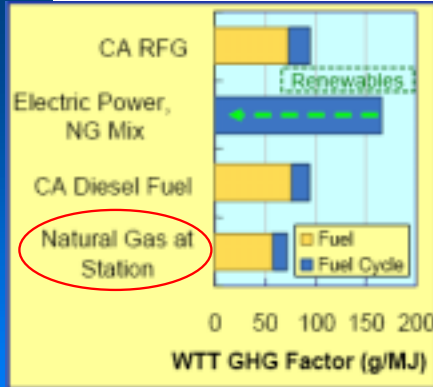
<b>Inputs</b>			
Types of Trucks	Class 1, 2, and 3	No. of Trucks	100
Hours/shift	4.0	Shifts/day	3
Days/year	250	Pick cycles/hr	30 - 90
Operator salary	\$20	H <sub>2</sub> tank size	1.5 - 3.0 kg
Hydrogen Price	\$5.00/kg	Electricity price	\$0.09/kWh
Fuel Cell Price	\$3,500/kW	Battery change time	25 min incl. travel time
<b>Outputs</b>			
Operating Hrs	3,000 HD/year	Hours Saved	21,200 hrs/yr
NPV	>0	IRR	>35%



This slide taken from USFCC Speciality Vehicles and Material Handling Presentation, Sept 20, 2007

## Environmental Benefits

### “Well-to-Tank” Greenhouse Gas Factors



Source: Societal Benefits Analysis, South Coast Air Quality Management District, Hydrogen Highway Network, 13 August 2004

- ❖ Hydrogen fuel cell vehicles have no GHG emissions
- ❖ GHG emissions are produced upstream as a result of hydrogen fuel production
- ❖ Other than electrolysis from renewable sources (wind, solar), producing hydrogen from natural gas at the station has the lowest carbon footprint
- ❖ GHG from Fuel Cell MHE Equipment are about half that associated with charging battery-powered forklifts

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		platform	2006	2007	2008	2009	2010
	<b>Pallet Trucks</b> (Class 3)	3 kW	Beta Units	Early Commercial Units	Commercial Quantities	→	
	<b>Stock Pickers</b> (Class 2)	3 kW		Beta Units	Commercial Quantities	→	
	<b>Reach &amp; Stand Up CB</b> (Class 2 & 1)	10 kW			Beta Units	Commercial Quantities	→
	<b>Sit down CB</b> (Class 1)	3 kW		Range Extender		→	
		10 kW				Beta Units	Commercial Quantities

*with doing right* This slide taken from USFCC Speciality Vehicles and Material Handling Presentation, Sept 20, 2007

# Ballard's Go-to-Market Strategy in Materials Handling

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BALLARD



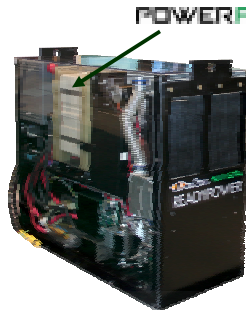
making fuel cells a commercial reality

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## Deka-Nuvera Total Power Solution (TPS)

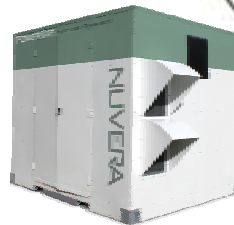
**DeLora NUVERA READYPOWER**

Hybrid fuel cell power pack for forklift trucks



**POWERTAP**

On-site hydrogen production and fast refueling for forklift trucks



- ❖ East Penn is a leader in motive power solutions—maker of Deka batteries
- ❖ Local service and support

This slide taken from USFCC Speciality Vehicles and Material Handling Presentation, Sept 20, 2007

**Hydrogenics HyPX<sup>®</sup> Fuel Cell Power Pack**

**Fully Integrated Solutions Fits Existing Battery Compartment**

- Hybrid system
- Fuel efficient
- Regen capable
- Quiet
- Durable
- Reliable

HyPM Power Module      Electrical & H<sub>2</sub> Storage  
 Thermal Management      Power Conditioning

This slide taken from USFCC Speciality Vehicles and Material Handling Presentation, Sept 20, 2007

**Hydrogenics HyPX Products For Materials Handling**

**Products for Class 1 lift trucks and Class 2 reach trucks**

<b>Delivering the HyPX<sup>™</sup> Product</b>		<b>HyPX<sup>™</sup>-1-27</b>	<b>HyPX<sup>™</sup>-1-33</b>	<b>HyPX<sup>™</sup>-2-21</b>
Nominal Voltage	V	36/48	36/48	36
Size (LxWxH)	mm	975 x 683 x 575	975 x 638 x 575	902 x 514 x 775
	in	38.5 x 26.9 x 22.7	38.5 x 25.0 x 22.7	35.5 x 20.2 x 30.5
Net Power - Peak for 30s	kW	21	21	16
Available Electrical Energy	kWh	21	21	21
Electrical Connection		Anderson SB-350	Anderson SB-350	Anderson SB-350
H <sub>2</sub> Fuel Storage Capacity	kg	1.8	1.8	1.8
	lb	3.9	3.9	3.9
H <sub>2</sub> Fuel Storage Pressure	bar	350	350	350
	psid	5000	5000	5000
H <sub>2</sub> Fuel Fill Port		SAE J2600	SAE J2600	SAE J2600
Ambient Operating Temperature	°C	> -5 to 35	> -5 to 35	> -5 to 35
	°F	> 41 to 95	> 41 to 95	> 41 to 95

Additional specifications available on request. Please contact us for information on the latest HyPX product releases.

**Products Ready for Pilot Deployments**

**Additional Products Under Development**

This slide taken from USFCC Speciality Vehicles and Material Handling Presentation, Sept 20, 2007





## Mobile and Permanent H<sub>2</sub> Refueling Options

Ready for Trials and Permanent Installations



### FedEx Toronto Airport Ramp

- Deployed mobile H<sub>2</sub> refueler
  - HySTAT Electrolyzer (20kg/day)
  - High Pressure Compressor (6000 psi)
  - H<sub>2</sub> Storage Tanks
  - H<sub>2</sub> Dispenser Module



### GM Oshawa Assembly Plant

- Deployed permanent H<sub>2</sub> refueler
  - Indoor H<sub>2</sub> Dispenser
  - HySTAT Electrolyzer (65kg/day)
  - High Pressure Compressor (6000 psi)
  - H<sub>2</sub> Storage Tanks

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## Operator Feedback and Impressions

2 FCPPs Deployed in Trucks at GM Plant and FedEx Ramp in 2005

Operator ratings:

- Truck operation: 6 out of 7
- Refueling: 6.3 out of 7

*“Quieter, no fumes, the power stays the same even though the gas gauge goes down.”*

*“Clean, comfortable, lots of power. Longer time between refueling compared to battery change.”*

*“Truck runs very quiet, smooth running.”*

*“Pick up in speed.”*

*“The lift is faster and quieter. There is a longer [period time] before refueling verses battery replacement. [The fuel cell forklift] is cleaner operating, there is no battery acid smell.”*



**Consistent and abundant power, quiet operation, lack of fumes and longer time between refueling**

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Play video testimonials of GM and FedEx here



## Future Projects

- New Canadian government contribution announced in July 2006 to fund up to 19 forklifts and tuggers at GM
- DOD awards
- Others



## Closing Remarks

- Productivity gains against battery powered forklifts make fuel cell hybrid powered forklifts an attractive early market
- The early market of fuel cell hybrid powered forklifts provide an accelerated path for fuel cell deployment in other applications
- Several fuel cell suppliers can provide solutions to the material handling market
- Continued and larger deployments are needed to fully commercialize the technology

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Find out more about us.....  
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