“Dedicated to The Continued Education, Training and Demonstration of PEM Fuel Cell Powered Lift Trucks In Real-World Applications”

Tom Dever – Program Director
LiftOne Division
Carolina Tractor & Equipment

Program Time: 9/1/2008 thru 8/31/2011

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“This presentation does not contain any proprietary, confidential, or otherwise restricted information.”

Technical Accomplishments / Progress

Deployment Program

- The program's six (6) Deployments of the two (2) CAT electric lift trucks each were conducted during the May 2009 – August 2010 time frame at six large companies. Each Deployment was for a one-month long period:

Fuel Cell Deployments

Self Grades - Sites 1 - 6

Site #	Participating Company	Time Frame	Grade	Comment
1	Stanley Tool - Concord, NC	May - June '09	A	Trucks ran well, efficiently
2	ABC Co. (name withheld by request)	July - Aug '09	C-	Component issues with fuel cell power packs
3	Bausch & Lomb, Greenville, SC	Oct - Nov '09	B	Trial went OK - low usage operation
4	BMW - Greer, SC	Nov - Dec '09	A	Excellent trial - high usage with 0 issues
5	Electrolux - Anderson, SC	Feb - Mar '10	A	Good trial - trucks worked well
6	AGI - In Store - Forest City, NC	July - Aug '10	A	Good trial - trucks performed well

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Technical Accomplishments / Progress

Deployment Program

▪ YEAR 1 - Some technical issues occurred, resulting from component parts failure on the Fuel Cell Power Packs. Site 2 in particular was not as successful as was hoped for.

Site # 1 - Stanley Tools - 30 days ran
* Truck / Cell #1 ran 300 hrs
* Truck / Cell #2 ran 230 hrs
* 89 kg of H2 used / 96 fuelings
* 5 minutes average fuel time
* 6.3 hrs avg run time per tank (1.6kg)
Notes: 1 defect with pump impeller
Straight forks - sideshifter application
Operators liked performance but the
heat exhaust in summer was a minus.

Site # 2 - "Company ABC" - 25 days ran
* Truck / Cell #1 ran 240 hrs
* Truck / Cell #2 ran 118 hrs
* 109 kg of H2 used / 89 fuelings
* 3.6 minutes average fuel time
* 5.3 hrs avg run time per tank (1.6kg)
Notes: Several repairs (see below)
One truck w / clamp, One with forks
Trucks ran OK, the high amp spikes
from clamp function was a factor. Heat.

▪ Site 2 issues were: A) water pump failure on 2 FCPP; B) pressure regulator; C) purge valve failure. D) Pump valve blade failure.

▪*The designed safety mechanisms did work and shut down the FCPP. The manufacturer has redesigned the components to avoid repeats.*

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Technical Accomplishments / Progress continued

Site # 3 - Bausch & Lomb - 22 days ran
* Truck / Cell #1 ran 34 hrs
* Truck / Cell #2 ran 45 hrs
* 24 kg of H2 used / 22 fuelings
* 2.7 minutes average fuel time
* 5.3 hrs avg run time per tank (1.6kg)
Notes: No defects experienced
Straight forks - sideshifter application
The lightest application. Trucks worked
well - hours were not high.

Site # 4 - BMW - 23 days ran
* Truck / Cell #1 ran 165 hrs
* Truck / Cell #2 ran 190 hrs
* 71 kg of H2 used / 62 fuelings
* 2.6 minutes average fuel time
* 8.0 hrs avg run time per tank (1.6kg)
Notes: Best deployment of all 5
Straight forks - sideshifter application
Trucks ran great. Fantastic run time.
Trial went well…moving forward.

Site #3 had low usage, yet the trucks did perform well. Very good results from site #4 (BMW) and LiftOne's efforts in the trial largely contributed toward the eventual adoption of over 80 fuel cell units at the Greer, SC new facility.

Technical Accomplishments / Progress

- YEAR 2: the program's 5th and 6th deployments were completed, with these results:

Site # 5 - Electrolux - 22 days ran
* Truck / Cell #1 ran 160 hrs
* Truck / Cell #2 ran 140 hrs
* 76 kg of H2 used / 73 fuelings
* 2.8 minutes average fuel time
* 6.5 hrs avg run time per tank (1.6kg)
Notes: 2 fueler issues corrected
Straight forks - sideshifter application
Another good trial with no problems.
Decent hours run. Operators liked.

Site # 6 - AGI - In Store: 25 days ran
* Truck 0264 / Cell # 17 ran 190 hrs
* Truck 0265 / Cell # 18 ran 229 hrs
* 86 kg of H2 used / 62 fills / 53.75 tanks
* 4.7 minutes average fuel time
* 7.8 hrs avg run time per tank (1.6kg)
Notes: water pump, purge valve
Straight forks - sideshifter application
Good trial - 2 technical issues fixed.
Decent hours run. Good time per tank.

- Site #5 had very good results, with no technical issues.
- Site #6 issues were: A) Cell #18: coolant low flow (water pump replaced on site); B) Cell # 17: purge valve irregularity.

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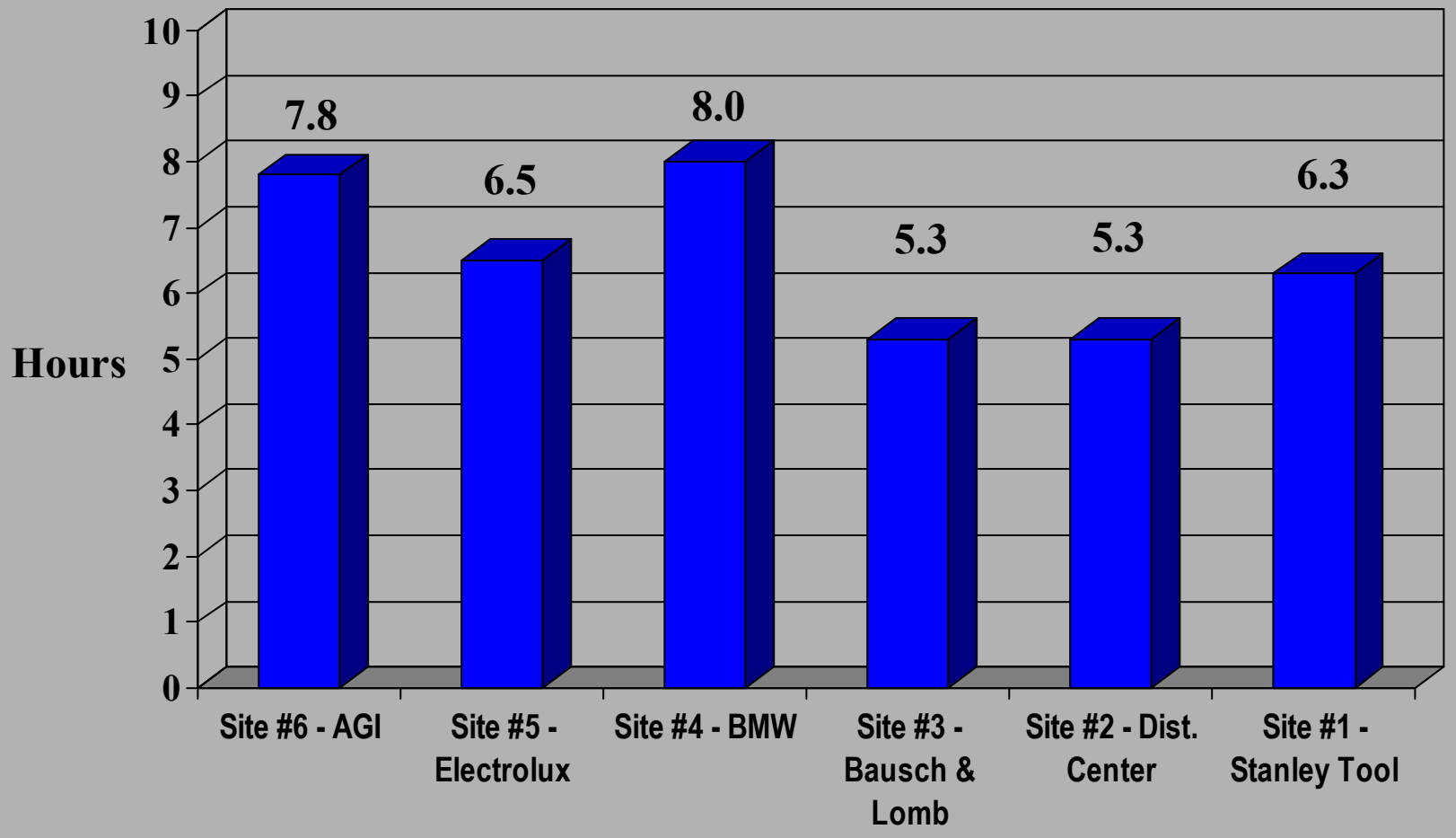
Technical Accomplishments / Progress continued

Program Deployment Sites
Hours Run - Per 1.6 KG Tank



Hydrogen “101”

Hydrogen Fuel Cell Power for the Material Handling (Lift Truck) Industry

Presented by Tom Dever
H_2 Program Director
LiftOne – Division of Carolina Tractor

NHA Hydrogen Conference
Hydrogen Business Solutions Forum
May 3, 2010

Changing power

…Powering change

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The Basics: Fuel Cells For Lift Trucks

Benefits

- Clean energy – no emissions
- Eliminating charging / changing batteries
- Doing the right thing by “Going Green”
- Increased productivity – less down time
- Optimum truck performance
- Recapturing substantial facility space

Concerns

- Cost for fuel cell packs and necessary infrastructure
- Cost of Hydrogen
- Permitting
- Safety items
- Operating costs

H_2 Fuel Cells For Material Handling

Common Battery Changing Stations

Multi-Level Battery Changers

Wall Mounted Fueling System

Fuel Cell Use in Material Handling
The Early Market Opportunity Becomes Reality

- The many successful deployments / trials executed by the main fuel cell manufacturers since 2005 have directly led to both immense product development and greater awareness of this form of "clean energy."
- These efforts by companies such as Plug Power, Nuvera, and Hydrogenics have led to more involved programs, seeing major companies acquire 20-200 fuel cell units put into multi-year commitments. Almost 2000 units have been sold in the US so far.
- Some companies that have taken the initiative include:

General Motors	**Defense Logistic Agency (DLA)**
Walmart	**Sysco**
East Penn Mfg.(Deka)	**Bridgestone-Firestone Tire**
Raymond Corp.	**GENCO**
Nestle	**FEDEX**
Anheuser-Busch	**Central Grocers**
Wegmans	**Coca Cola**

……and several more on the brink

Market Breakout Session Topics….

- Application studies / operator comments
- Performance analysis
- Productivity examination
- Infrastructure / fueling methods
- Basic Cost Snapshots
- Permitting facts
- Tax Incentives Available for Fuel Cells / Infrastructure

Hydrogenics forklift at General Motors facility

Break-Out Session

Hydrogen Fuel Cell Power for the Material Handling (Lift Truck) Industry

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Market Breakout Session Topics….

- Application studies / operator comments
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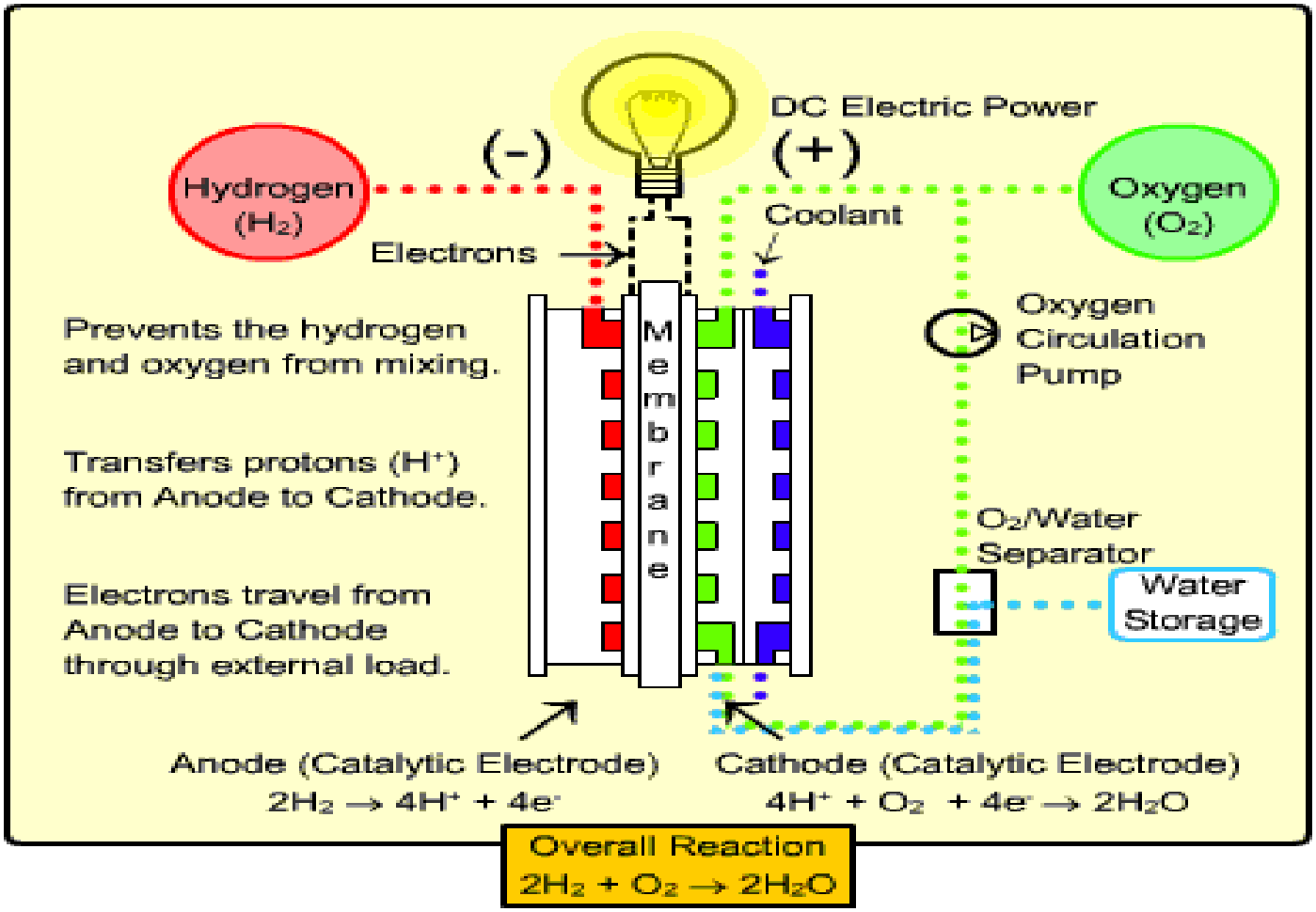
H_2 Fuel Cells For Material Handling

Fuel Cell Process



Batteries vs Hydrogen PEM Fuel Cells

vs.

The Case...Batteries take up space!

- Electric lift trucks utilize lead-acid batteries to provide stored power
- High hour applications typically require 3 batteries per truck, with these approximate weights by class:

Sit Down Rider Trucks (Class I)

36 / 48 Volt battery weight range is 2,200 - 4,000 lbs

Electric Lift Truck Batteries

Narrow Aisle “Reach” trucks (Class II):

24 / 36 Volt battery weight range is 1,400 - 2,800 lbs

Electric pallet jacks / Tuggers (Class III):

24 Volt battery weight range is 500 - 1,200 lbs

Common Battery Changing Stations

Multi-Level Battery Changers

Wall Mounted Fueling System

Portable Hydrogen Fueler Used At Temporary Deployments - To Refuel Lift Truck Fuel Cells

Infrastructure….

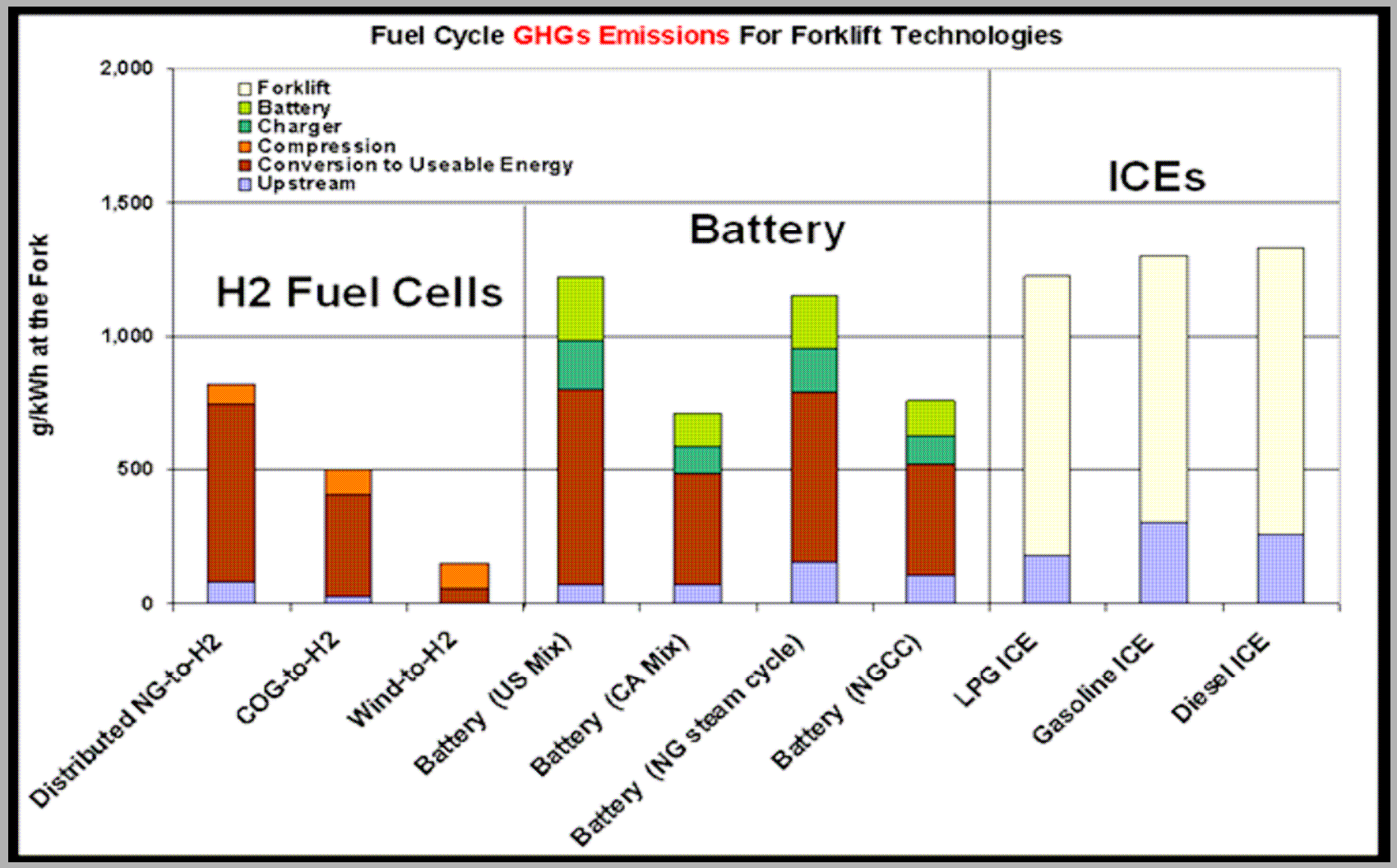
Outdoor liquid hydrogen storage

Indoor dispenser

Common Stationary Facility Safety Systems

- Pressure relief devices – rupture disks, pressure relief valves and safety vents
- Leak detection, flame detection
- Design elements :
  - **Siting to established codes**
  - **Engineering safety margins and analysis**
  - **Use of hydrogen-compatible materials**
- Monitoring, controlled access and emergency stops

Comparison of Greenhouse Gas Emissions for Forklift Technologies



From the Argonne National Laboratory - Energy Systems Division Study # ANL/ESD/08-3, "Full Fuel-Cycle Comparison, Forklift Propulsion Systems", October 2008.

Profile of a Hydrogen Fuel Cell Candidate

- Ideally, facilities operating approximately 35 - 40 sit down electric rider lift trucks (Class I), or narrow-aisle units (Class II), or a high volume 50 + electric pallet jack / tugger (Class III) application.
- Best candidates run 3 shifts and operate for the most part 7 or perhaps 6 days per week.
- High hours, perhaps a minimum of 4000 annually per lift, ideally in a distribution type application with high throughput.
- 3 batteries per truck make for the best business case. With this normally comes the required sq. footage for charging, and the added expense / downtime for battery changing.
- Battery maintenance and potential problems due to improper charging. “Battery Culture” issues….
- Gaining back the facility space required for battery rooms + equip. for switching batteries is critical at many sites.
- Companies looking for a viable “clean energy” alternative.

The Case for H2 Fuel Cells

- **Lead-acid batteries are an established technology with proven reliability. From an operations and maintenance standpoint, however, there are several challenges.**
- **Batteries have a limited range, take substantial time to recharge and cool before reuse, are prone to voltage drops as power discharges, and create downtime during battery change-outs (which can take from 15 to 30 minutes in many operations).**
- **Fuel cells for lift trucks can last 7- 10 hours per fill, while refueling takes about 2 minutes.**
- **In a 3 shift operation with high lift truck usage and 3 batteries per lift truck……the potential exists to *SAVE UP TO 50 MINUTES PER TRUCK / PER DAY*……by using a single Fuel Cell Power Pack and eliminating all battery changes.**

- ***Up time and productivity are direct benefits of the efficiencies.***

Sample Comments from Operators

- “Constant power was good….no drop off.”
- “No smell of battery acid….that was good.”
- “No heat coming from under the seat & against my legs like we have with the battery trucks.”
- “Much quieter ride.” (At an LP Gas truck application)
- “I liked the steady power, no drop off toward the end, like we get with the batteries.”
- “The chance to never have to change out batteries again would be great.”
- “Fueling was pretty easy – it took 2 minutes!”
- “No pulling the battery connectors apart, which is tough to do. The nozzle was easier to connect to the fuel cell.”
- “I don’t like having to use the overhead gantry crane to change the big batteries. It is dangerous.”

Some basis points to take into account…

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POSTIVE FUEL CELL FEATURES

- Workman's comp claims related to handling batteries are an expensive reality for many. One customer stated that 2 incidents have cost them well over $ 120,000 in the past year.
- A 3-shift schedule could involve an annual electric bill of up to $ 4,000 per charger, depending on the cost per kw/hr.

  50 chargers = $ 200,000 annually

  100 chargers = $ 400,000 annually
- The greatest benefit is productivity and up-time. The average is 17 minutes per battery change:

  2 shifts = 34 min. vs 4 minutes per day for H_2 fueling

  3 shifts = 51 min. vs 6-8 minutes per day for H_2 fueling
- When we speak about the steady power with no low voltage that fuel cells offer, fleet owners listen. Electric component damage and motor failures due to low voltage operation is another costly reality for most electric fleet owners. This will not happen with fuel cells.

Are fuel cells efficient in lift trucks?

Yes

- No low voltage situations
- Average 1.8 – 2.0 kg tank capacity allows for 7-10 hrs of constant power per tank for Class 1 (Sit-down riders).
- Better in most cold storage operations.
- Ease of refueling is a reality.

??

- Hot / non-climate controlled applications are not particularly ideal, as current models operate OK - up to 110 deg. F.
- Some issues have occurred when multiple function / high demand attachments (clamps, rotators) are used.
- The fuel cell manufacturers have designed more power for their models to deal with this.
- Maintenance for fuel cells are higher than properly maintained batteries.

Fuel Cells available for Federal Tax Incentives

- On October 3rd, 2008, Congress passed and President Bush signed into law a highly anticipated eight-year extension of the Investment Tax Credit (ITC) for fuel cell technology.
- **The tax credit extension is Valid until December 31st, 2016**
- The ITCs for residential and business fuel cells include the following:

  BUSINESS PROPERTY OWNER (Section 103)

  Credit of 30% of the cost up to $3,000 per kW

  Minimum 0.5 kW capacity

  Valid until December 31st, 2016

  Electricity-only efficiency of more than 30%
- Allowance of Credit is permissible against Alternative Minimum Tax. This allows persons subject to AMT to take the credit against that portion of their tax liability**.**
- Fuel cells **ARE CURRENTLY ELIGIBLE** for a Federal tax credit **up to $3,000/kW.**
- In some situations, the operations and maintenance savings associated with fuel cells do provide a financially attractive payback.

And as a result of this…

Q: How do the 30% incentive and dollar-per-kilowatt cap work?

A: The magnitude of the credit is determined by the size and cost of the fuel cell. To determine the credit for business property, multiply the cost of the unit by 30%. Next, multiply the rated output in kilowatts , by $ 3,000.

Your credit is the smaller of the two amounts.

Q: Are fuel cells for forklifts and other industrial equipment eligible for this?

A: Yes. According to the IRS Bulletin 2008-34, Sec. 5.02, the credit is allowed with respect to a taxpayer's mobile fuel cell power plant if the plant satisfies the size , efficiency and output conditions.

Infrastructure Cost Assistance Available…

The most recent Stimulus bill provides for:

- ***Hydrogen Infrastructure ITC allows for a credit of 30% of refueling property up to $200,000.***
- ***Most infrastructure costs for on-site storage / compression and indoor dispensing will involve this $ amount.***
- ***Since most infrastructure equipment is leased, the gas supplier usually takes the credit and passes it on to the user.***

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INFRASTRUCTURE COMPARISON / HARD LINE COSTS BATTERY vs H2

3 shift Operation - Annual / 5 year Analysis 40 trucks - Class 1 sit downs

Assumption: 3 shifts per day / 7 days per week 10 holidays (350 days per year)

36 / 48 V Batteries	Item Description	Hydrogen Fuel Cells
$164,000	40 Chargers @ annual rate of $ 4,100 each for electricity	
$210,000	Battery changers - 1 dedicated per shift @ $70,000 per person (burdened rate - low)	
$37,500	Battery storage / charging / changing room 2,500 sq ft x $ 75 = $ 187,500 / 5 years	
$5,000	Battery changer maintenance averages $ 5,000 per year	
	Hydrogen Infrastructure: Includes all equipment for storage, compression, dispensing,	$258,000
	installation & maintenance	
$416,500	ANNUAL TOTAL	$258,000
$2,082,500	5 YEAR TOTAL	$1,290,000

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INFRASTRUCTURE COMPARISON / HARD LINE COSTS BATTERY vs H2 * with batt / chrg & H2

3 shift Operation - Annual / 5 year Analysis 40 trucks - Class 1 sit downs

Assumption: 3 shifts per day / 7 days per week 10 holidays (350 days per year)

36 / 48 V Batteries	Item Description	Hydrogen Fuel Cells
$164,000	40 Chargers @ annual rate of $ 4,100 each for the electricity	
$187,200	Cost of 3 batteries / 1 charger per truck = $ 23,400 x 40 = $ 936,000 / 5 years	
$210,000	Dedicated personnel to staff battery room & change - 1 dedicated per shift @ $70,000 per	
	person (burdened rate - low). Includes watering	
$37,500	Battery storage / charging / changing room 2,500 sq ft x $ 75 = $ 187,500 / 5 years	
$5,000	Battery changer maintenance averages $ 5,000 per year	
	Hydrogen Infrastructure: Includes all equipment for storage, compression, dispensing,	$258,000
	installation & maintenance	
	H2 supply during year: Calculated at 4 kg @ $ 7 per kg / per truck / per day = 1400 kg per year	$392,000
	per truck. 1400kg x 40 = 56,000 kg of H2 per year @ $ 7 per kg.	
$603,700	ANNUAL TOTAL	$650,000
$3,018,500	5 YEAR TOTAL	$3,250,000

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Presented by Tom Dever
H2 Program Director
LiftOne – Division of Carolina Tractor
Charlotte, North Carolina

Fuel Cell & Hydrogen Energy Conference
February 14, 2011

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LiftOne / DOE - H2 Education Program

- Project Scope / Project Timeline
- Implementation
- Education Session Development
- Lift Truck / Fuel Cell Deployments / Results
- Reception / Feedback from participants
- Opportunities / Future Plans

LiftOne H2 Education Project Scope

- Developed with the assistance of the DOE Grant
- Designed to build further upon the successful LiftOne deployments executed in 2007, as a part of the "Greater Columbia, SC Fuel Cell Challenge"
- Two Program Segments:
  1. Education Segment
  2. Deployment Segment

Hydrogenics forklift at General Motors facility

- Educating a broad group of stakeholders throughout North Carolina, South Carolina and Virginia to the benefits of fuel cell and hydrogen technology

LiftOne / DOE - Project Timeline

Education Segment : 36 Months

Deployment Segment: 14 Months

- **September 2008: DOE Award received**
- **1st Qtr 2009: H2 Education Sessions begin**
- **2nd Qtr 2009: Lift truck deployments start**
- **3rd Qtr 2010: 6th / Final deployment concludes**
- **Education to continue through August - 2011**

Implementation of H2 Education Sessions:

The sessions have been held with companies at LiftOne's 7 Branch Locations:

- **Charlotte, NC (185,000 Sq. Ft.) - Headquarters**
- **Asheville, NC (50,000 Sq. Ft.)**
- **Hickory, NC (23,000 Sq. Ft.)**
- **Greensboro, NC (32,000 Sq. Ft.)**
- **Greenville, SC (12,000 Sq. Ft.)**
- **Columbia, SC (9,400 Sq. Ft.)**
- **Roanoke, VA (25,000 Sq. Ft.)**

Additional H_2 Education Sessions With:

- American Textile Engineering Association
- North Carolina Truck Maintenance Council
- North American Council of Automotive Teachers
- Concord-Kannapolis Fire Dept.
- University of SC, Central Piedmont CC
- At several regional “Green” Business Expos
- Odyssey Week events in 2010

Sessions always include a “live”demo of a H2 fuel cell powered truck.

LiftOne / DOE - H2 Education Course Content

- H2 Properties / applications in industry
- Fuel Cell design / applications, PEM fuel cells for material handling
- Performance review from LiftOne Deployments
- Infrastructure outline and discussion
- Cost comparisons and scenarios
- Tax incentive discussion

H_2 Fuel Cells For Material Handling

Multi-Level Battery Changers

Wall Mounted Fueling System

INFRASTRUCTURE COMPARISON / HARD LINE COSTS BATTERY vs H2 * with batt / chrg & H2

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	per truck. 1400kg x 40 = 56,000 kg of H2 per year @ $ 7 per kg.	
$603,700	ANNUAL TOTAL	$620,000
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LiftOne H2 Education Course Feedback

- Companies have great intrigue concerning the the fuel cell option
- Education session attendees have voiced their frustration with present battery handling / charging, storage, poor performance issues
- There has been great interest concerning the performance reviews on fuel cells thus far
- At the end of the day, it comes down to the cost element and benefit analysis - “Up time”
- Serious consideration has also been given to the tax incentives and funding available
- Reviews of the LiftOne Education sessions have been positive and well received

Deployment Segment: 2009-2010

Deployment Sites

- Stanley Tool – Kannapolis, NC
- Retail Distribution Center - In Hickory, NC area
- Bausch & Lomb - Greenville, SC
- BMW – Greer , SC
- Electrolux - Anderson, SC
- AGI – In Store, Forest City, NC

LiftOne's Hydrogen Fuel Cell Program

2007 **2009-2010**

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LiftOne / DOE - Deployment Format

- Introduce companies operating large electric fleets to the H_2 fuel cell power alternative, by deploying (2) CAT 5000 lb - Class 1 / Electric sit-down rider units for 1 month long trials.
- Interaction with all local Fire Departments
- First Day Hydrogen Safety Training / Orientation sessions for all shifts.
- Hydrogenics model HyPX1-33 PEM Fuel Cell Power Packs used for each deployment.
- Air Products HF-150 Mobile Fueler for refueling
- On site monitoring / data collection by LiftOne

LiftOne / DOE - Post Deployment

- Interviews conducted with all participating company operators / managers
- Review Meetings were held with full performance data analysis and cost propositions provided
- Fuel Cell performance data was analyzed by Hydrogenics' engineering staff and formatted for submission to NREL
- The CAT trucks used during the deployments have also been used at the National Hydrogen Association Conference in 2009 in Columbia and other high profile events to heighten awareness

LiftOne – Deployment Data Snapshots

Site # 1 - Stanley Tools - 30 days ran
* Truck / Cell #1 ran 300 hrs
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* 2.6 minutes average fuel time
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Notes: Best deployment of program
Straight forks - sideshifter application
Trucks ran great. Fantastic run time.
BMW ordered 80+ Fuel Cells from Plug.

More LiftOne – Deployment Data Snapshots

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Notes: 2 fueler issues corrected	Notes: water pump, purge valve
Straight forks - sideshifter application	Straight forks - sideshifter application
Another good trial with no problems.	*Good trial - minor issues.*
Decent hours run. Operators liked.	*Decent hours run. Good time per tank.*

Conclusions / Opportunities

- We feel as though the LiftOne - DOE Hydrogen Education Program has played a major role towards increasing Hydrogen Awareness in NC, SC and Va.
- Great exposure from the deployments and working demos at the regional Green Expos
- The cost equation remains a major obstacle for many companies considering the Hydrogen Fuel Cell option for their electric fleets
- Costs will come down, technology will continue to improve and alternative hydrogen production solutions will surface
- Many companies are on hold!!