



# Hydrogen Industrial Trucks

DOE Hydrogen Technical Advisory Committee  
Aaron Harris Oct 2010

# Nurturing Products to the Market

---



- Fuel Cell and hydrogen generator development initiatives.
- Research studies to evaluate, predict possible impact of technology.
- Policy activities to coordinate support

## Development

- Sponsored projects to prove technology in applications



- Research to troubleshoot roadblocks
- Industry advocacy to coordinate industry partners (standardize)

## Demonstration

- Incentivized market to promote commercial sales
- Research to advance and ensure safety
- Industry groups assume responsibility for standards

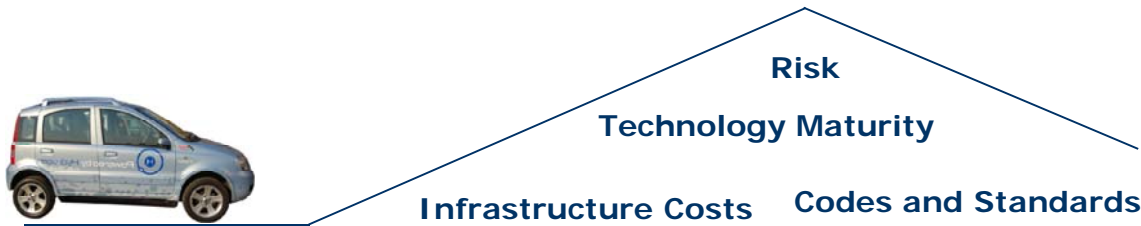


## Deployment

# Meeting the Goals

2002 National Hydrogen Energy Roadmap Goal:

“Coordinate 4 industrial segments (Production, Delivery, Storage, Application) as one system”



## Keys to Success:

- Captured Fleets
- Field Experience
- Simplified Infrastructure



## What is the hydrogen industrial truck market?

**Captured Fleets** – 1 warehouse = 10's – 100's vehicles

**Field Experience** – High volume warehouses run 24/7

**Simplified Infrastructure** - Single storage feeds multiple refueling sites

# Experience in Code and Standards

If codes and standards development relies on **experience...**  
then industrial truck markets provide substantial experience.



## Automotive Hydrogen Use

- 70-90 Million new cars/year
- 4-7 kg storage , 300 miles/fill, 1-2 fills/week...
- 8-10 kg per week per vehicle
- 0.5 - 1 kg/day
- **300-500 kg in 25 year life**
- Current US Vehicle Fleet: 300-400 vehicles



## Industrial Truck Hydrogen Use

- 0.2 Million new industrial trucks/year
- 1-2 kg storage, 15-20 fills/week...
- 40 kg per week per vehicle
- 3-4 kg/day
- **4000 – 6000 kg in 10 year life**
- Current US Vehicle Fleet: 1000+ vehicles

# 'Niche' to 'Broad' Market Comparison

## Similarities

*Engineering Development* - fuel cell/battery hybrid vehicle systems, high-pressure hydrogen storage, regenerative braking, "Fuel Cell Range Extenders"

*Safety* - storage vessel performance, leak detection strategies, impact detection strategies, refueling

*Codes and Standards Gaps* – end of life control, aftermarket, consumer product vs. industrial use



## Differences

*Engineering Development* - weight, tank size and pressure, power requirements, vehicle integration, indoor fueling

*Safety* – driver training, regulatory agency

*Codes and Standards Gaps* – use type 1 tanks, indoor refueling standards



# Hydrogen Warehouse

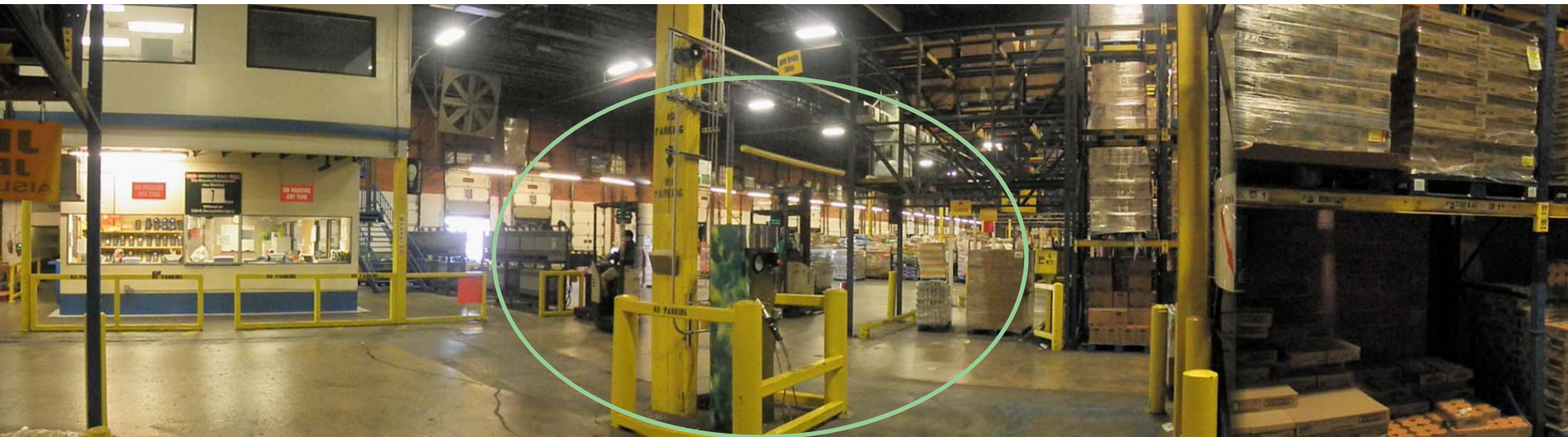


## Hydrogen meets the end-user's goals:

- Increase productivity
- Optimize floor space
- Optimize energy costs
- Improved corporate image

## Proven fuel cell advantages:

- Refueling vs. Recharging
- Replace indoor battery charger with outdoor On-Site generation and storage
- On-Site Generation = on-demand generation
- "Green", Retail brand names associated with national energy/security policies



# Component Introduction



1. Onsite Hydrogen Generation
2. Outdoor Compression and High Pressure Storage
3. Indoor Dispensing
4. Battery replacement in existing electric forklifts



# Current Status (Published Docs in bold)

## Industrial Vehicle

Forklift  
**NFPA 505**  
**UL 583**  
**UL 2267**  
 (Integrated FC system)



## Indoor Dispenser

Dispenser  
**NFPA 52**  
 HGV 4.3  
 HPIT 2



Fuel Cell Power System  
**UL 2267**

Fuel Cell Power System  
 (Battery Replacement)



Indoor Refueling Guidelines  
**NFPA 52**  
 HPIT 2

350 Bar Fueling Receptacle/Nozzle Pair  
**SAE J2600**

## Dispenser Component Standards

Hose – HGV 4.2  
 Breakaway – HGV 4.4  
 Priority and Sequencing – HGV 4.5  
 Manual Valves – HGV 4.6  
 Automated Valves - HGV 4.7

## Fuel Cell System Components

Energy Storage – Batteries, Ultra-Caps  
 Regenerative Braking Dissipation  
 H2 Detectors/ Proof of Ventilation  
 Fuel Cell Stack and BOP



Hydrogen Pressure System  
**SAE J2919**

## Hydrogen Pressure System Components

**CSA HPIT 1**

- Cylinders, valves, fittings, tubing



# Defining the Gaps

---

## Overall Assumptions

- No one would want to put a steel tank on a vehicle
  - Forklifts use batteries as the counterweight
    - Therefore steel tanks are feasible
  - Steel tanks: low tech, low cost, fast fill w/o strict temp compensation
- Niche markets will not grow faster than automotive
  - Current deployments: 200 - Cars      1000 - Forklifts
- Refueling cycles are not a concern
  - Cars = 1800 cycles in 20 years      Forklift = 10,000 cycles in 10 years
- Refueling standards are sufficient for all markets
  - Indoor Fueling
  - Use of the same nozzle/receptacle



# Defining the Gaps

---

## Specific Gaps

- No available tank standard sufficient for the application
  - UL 2267 - 2006 – 4 tank standards referenced:
    - ASME BPVC Section VIII
    - DOT - subsequently interpreted as DOT 3AA
    - NGV2 – no HGV2 at publication
    - ISO 11119-1
  - Cycle fatigue phenomena and high cycle use application
- UL2267 – removable cylinders allowed
- UL 2267 - No link to component level or refueling standards
- HGV2 only applies to on-road vehicles
- NFPA 52/HGV 4.3 - Insufficient guidelines for safe dispenser function



# Addressing the Gaps

## Industrial Vehicle

Forklift  
**NFPA 505**  
**UL 583**  
**UL 2267**  
 (Integrated FC system)



## Indoor Dispenser

Dispenser  
**NFPA 52**  
**HGV 4.3**  
**HPIT 2**



Fuel Cell Power System  
**UL 2267**

Fuel Cell Power System  
 (Battery Replacement)



Indoor Refueling Guidelines  
**NFPA 52**  
**HPIT 2**

350 Bar Fueling Receptacle/Nozzle Pair  
**SAE J2600**

## Dispenser Component Standards

Hose – HGV 4.2  
 Breakaway – HGV 4.4  
 Priority and Sequencing – HGV 4.5  
 Manual Valves – HGV 4.6  
 Automated Valves - HGV 4.7

## Fuel Cell System Components

Energy Storage – Batteries, Ultra-Caps  
 Regenerative Braking Dissipation  
 H2 Detectors/ Proof of Ventilation  
 Fuel Cell Stack and BOP



Hydrogen Pressure System  
**SAE J2919**

## Hydrogen Pressure System Components

**CSA HPIT 1**

- Cylinders, valves, fittings, tubing

# Acknowledge the Support Network

---

Consider, in 1 year...

- Testing programs at National Lab coordinated with Industry
- Changes affecting approximately ~15 documents
- Coordinating various entities to generate those documents:
  - Fuel Cell Companies
  - Industrial Truck OEMs
  - Industrial Gas Suppliers
  - Code Development Organizations
  - Department of Energy
  - National Laboratories

How did we get here...

- Identified Gaps through DOE sponsored pool of experts (HIPOC)
- Discussed in DOE sponsored monthly coordinating call (USFCCSC)
- Continued planning through USFCC as a DOE contractor (USFCC)
- Identified need for testing, supported by DOE (H2 Safety Panel)
- Test Planning (DOE, Sandia, Plug, Nuvera, Norris, CSA)
- Ongoing Standards development (UL2267, CSA-HPIT1, SAE J2919)



# Open Technical Items

---

## Counting Fill Cycles

- Cyclic fatigue concerns requires close monitoring of fill cycles on each tank



## Decommissioning Tanks At End of Life

- Regulation and the aftermarket

## Cylinder Handling

- Design and manufacture only as good as the installation



## Escapee Scenario

- Use of SAE J2600 Nozzle/Receptacle for two separately regulated markets
- Forklift refueled at retail gas station
- Car refueled at warehouse or industrial truck fleet fueling station



# Open Market Items

---

## Codes and Standards Harmony and Implementation

- Harmony - UL 583, UL 2267 and NFPA 505
- Implementation – Comprehensive revision to UL2267 to reflect industry standards
- Implementation – Interpretation issues with “new” separation distance tables in NFPA

## Government Policy/ Codes and Standards Interaction

- Regulatory Parent Agencies and Involvement
  - Industrial Trucks – OSHA – Dept of Labor
  - Automotive - FMVSS – Dept of Transportation

## Certification and Customer Confidence

- Hurdle for small companies to pursue certification of not yet proven product
- Certification path not yet clearly defined
- Difficult for customers to trust uncertified products
- Less diverse customer base (not as many enthusiasts)
- Customers need gentle nudge to field new technology



A world map where the landmasses are filled with a dense pattern of small, glowing yellow and white dots, representing city lights at night. The background is a dark, deep blue.

**NUVERA**  
FUEL CELLS

EXPERIENCE

**The Future of Energy<sup>®</sup>**