



# Early Lessons Learned from DLA Hydrogen Demonstration Projects

Environment, Energy Security & Sustainability  
Symposium and Exhibition

Stu Funk, Program Manager, LMI (supporting DLA)

May 12<sup>th</sup>, 2011

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                                                  | Form Approved<br>OMB No. 0704-0188                  |                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-------------------------------------|------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. |                                    |                                     |                                                                  |                                                     |                                    |
| 1. REPORT DATE<br><b>12 MAY 2011</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                    | 2. REPORT TYPE                      |                                                                  | 3. DATES COVERED<br><b>00-00-2011 to 00-00-2011</b> |                                    |
| 4. TITLE AND SUBTITLE<br><b>Early Lessons Learned from DLA Hydrogen Demonstration Projects</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                    |                                     |                                                                  | 5a. CONTRACT NUMBER                                 |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                                                  | 5b. GRANT NUMBER                                    |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                                                  | 5c. PROGRAM ELEMENT NUMBER                          |                                    |
| 6. AUTHOR(S)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                                                  | 5d. PROJECT NUMBER                                  |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                                                  | 5e. TASK NUMBER                                     |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                                                  | 5f. WORK UNIT NUMBER                                |                                    |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>LMI,2000 Corporate Ridge,McLean,VA,22102-7805</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                    |                                     |                                                                  | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER         |                                    |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                    |                                     |                                                                  | 10. SPONSOR/MONITOR'S ACRONYM(S)                    |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                                                  | 11. SPONSOR/MONITOR'S REPORT<br>NUMBER(S)           |                                    |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release; distribution unlimited</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                    |                                     |                                                                  |                                                     |                                    |
| 13. SUPPLEMENTARY NOTES<br><b>Presented at the NDIA Environment, Energy Security &amp; Sustainability (E2S2) Symposium &amp; Exhibition held 9-12 May 2011 in New Orleans, LA. U.S. Government or Federal Rights License</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                                                  |                                                     |                                    |
| 14. ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                                                  |                                                     |                                    |
| 15. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                                                                  |                                                     |                                    |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     | 17. LIMITATION OF<br>ABSTRACT<br><b>Same as<br/>Report (SAR)</b> | 18. NUMBER<br>OF PAGES<br><b>23</b>                 | 19a. NAME OF<br>RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |                                                                  |                                                     |                                    |

# Defense Logistics Agency (DLA)



- Department of Defense's largest logistics combat support agency
- Provides worldwide logistics support in war and peace time
- Supports military and civilian agencies
- Good testing ground for hydrogen-powered equipment



# DLA Demonstration Projects



- Material handling equipment (MHE)
- Transportation and infrastructure
- Solid hydrogen storage
- Extended range utility vehicles





# DLA's Hydrogen Fuel Cell R&D Goals

- To be an early adopter and principal demonstrator
- To foster competition in the marketplace and provide a market demand
- To support improved Technology and Manufacturing Readiness Levels by:
  - Exercising the supply chain
  - Testing under real world conditions
  - Providing feedback to manufacturers
- To highlight the business case for fuel cells
- To transition the technology

Suppliers are already commenting on the positive impact the program is having on the supply chain!

# Business Case Analysis



- Gathering cost and functional data about forklift operations, maintenance, and infrastructure to compare fuel cells and incumbent power sources
- Will help determine viability in DLA operations, and identify conditions under which fuel cell forklifts make sense

156,000+ operating hours  
34,000+ refuelings  
19,000+ kg of H2 dispensed

# Hydrogen and Fuel Cell R&D Program



## Objectives:

- Be an early adopter and principal demonstrator
- Provide market demand & exercise the supply chain
- Support improved Technology and Manufacturing Readiness Levels

## Approach:

- 2-year forklift pilot projects at 3 DLA warehouses and JBLM (114 forklifts, 1 bus, 4 utility vehicles)
  - 4 different hydrogen production techniques
  - Team with DOE to analyze business case
- Solid hydrogen storage & extended range vehicles
- Working to transition from R&D to full operations

## Customers:

- DLA Distribution Susquehanna, PA, Warner Robins, GA, San Joaquin, CA
- Joint Base Lewis-McChord (JBLM)
- Hydrogen and fuel cell industrial base

## DoD Benefits:

Support DoD Energy Strategy:

- Promote energy independence
- Reduce the environmental impact
- Improve operational efficiencies

**Performers:** Air Products, CTC, CTE, Plug Power, Hydrogenics, East Penn, Nuvera, Gas Tech Inst, Proterra, ATK

## Schedule/Milestones:

- Susquehanna, PA demonstration – Feb 09 to Sep 11
- Warner Robins, GA demonstration – Nov 09 to Nov 11
- JBLM opening – Jul 11
- San Joaquin, CA opening – Aug 11

**Funding:** FY07-10 \$39.1M

# Fuel Cell Pilot Project

## DLA Distribution Susquehanna, PA



### Objectives:

- Explore fuel cell infrastructure and functionality in place of lead acid batteries in forklifts
- Develop a business case for fuel cells
- Collect and analyze operational data

### Approach:

- 2-year pilot project
- 55 forklifts with fuel cells (20 existing lifts and 35 new leased lifts)
- Compare products from two fuel cell producers
- Set up storage & indoor dispensing systems for delivered liquid H<sub>2</sub>

**Customers:** DLA Distribution Susquehanna, PA

### DOD Benefits:

- Develop knowledge of fuel cell powered fork lift capabilities, costs, limitations, and benefits
- Improve Manufacturing Readiness Levels (MRLs) and costs

**Performers:** Air Products, Plug Power, East Penn/Nuvera

### Schedule/Milestones:

- Contract award – Aug 2007
- Operational phase – Feb 2009 to Sep 2011
- Interim business case analysis – Dec 2009
- Transition decision – Summer 2011

# Fuel Cell Pilot Project

## DLA Distribution Warner Robins, GA



### Objectives:

- Expand infrastructure exploration to include on-site reformation and mobile refueling
- Continue to develop business case for fuel cells
- Analyze operational data

### Approach:

- 2-year pilot project
- 20 new forklifts with FCs + 2 CL II lifts added (6/11)
- H<sub>2</sub> reformed on site from natural gas
- Test mobile refueling

**Customers:** DLA Distribution Warner Robins, GA

### DOD Benefits:

- Further knowledge of fuel cells, on-site reformation, and mobile refueling
- Improve Manufacturing Readiness Levels (MRLs) and costs for fuel cells and infrastructure

**Performers:** Concurrent Technologies Corporation, Air Products, Hydrogenics, Ballard (4/11)

### Schedule/Milestones:

- Contract award – Jun 2008
- Construction start – Aug 2009
- Operational phase – Nov 2009 to Nov 2011
- Transition decision – Fall 2011

# Fuel Cell Pilot Project

## Joint Base Lewis-McChord (JBLM), WA



### Objectives:

- Explore H<sub>2</sub> production from wastewater digester gas
- Expand knowledge base for fuel cell applications
- Continue to develop business case
- Analyze operational data

### Approach:

- 2-year pilot project
- 19 new FC forklifts
- 1 Fuel Cell Hybrid Bus
- “Green” H<sub>2</sub> production source
- Hub and spoke H<sub>2</sub> distribution

**Customers:** US Army (Depts. of Public Work & Logistics), Joint Base Lewis-McChord (JBLM), WA

### DOD Benefits:

- Expanded knowledge of fuel cell costs and benefits for renewable H<sub>2</sub>
- Improve Manufacturing Readiness Levels (MRLs) and costs for fuel cells and tri-generation systems
- Explore and support sustainable closed loop operations

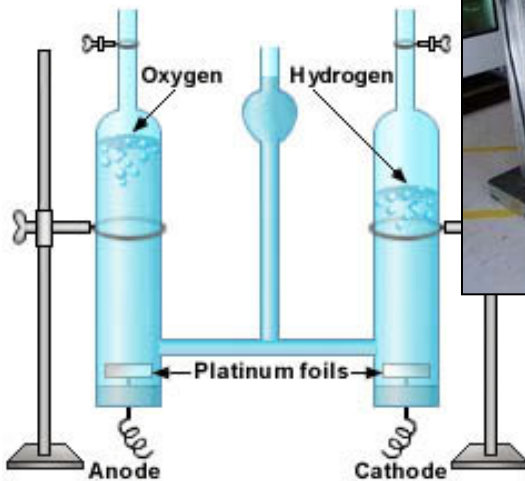
**Performers:** Center for Transportation and the Environment (CTE), Air Products, GTI/Versa, Plug Power, Proterra

### Schedule/Milestones:

- Contract award – Jun 2009
- Construction start – Fall 2010
- Operational phase – Jul 2011 to Jul 2013

# Fuel Cell Pilot Project

## DLA Distribution San Joaquin, CA



### Objectives:

- “Green” H<sub>2</sub> production from photovoltaics
- Replace propane combustion powered forklifts
- Analyze operational data
- Continue to develop business case (compare to propane operations)

### Approach:

- 2-year pilot project
- Replace 20 propane forklifts with FCs
- Generate H<sub>2</sub> on-site using solar energy
- DLA-E negotiate a Solar Power Purchase Agreement

**Customers:** DLA Distribution at San Joaquin, CA

### DOD Benefits:

- Expanded knowledge of fuel cell costs and benefits
- Improve Manufacturing Readiness Levels (MRLs) for fuel cells and electrolyzers
- “Green” hydrogen – reduced CO<sub>2</sub> emissions

**Performers:** CTE, APCI, Proton Energy, Plug Power

### Schedule/Milestones:

- Contract award – Apr 2010
- Construction start – Apr 2011
- Solar PPA – Summer 2011
- Operational phase – Aug 2011 to Aug 2013

# Fuel Cell Pilot Project

## Extended Range Utility Vehicles



**Objectives:** Investigate and implement new designs to promote extended vehicle range for H<sub>2</sub> fuel cell-powered vehicles

### Approach:

- Phase I: design novel H<sub>2</sub> storage to extend range of fuel cell utility (three awards)
- Phase II: construct and integrate the technology into vehicles supporting installation activities (Two different designs constructed; ATK & CTE)
- Utilize excess H<sub>2</sub> capacity
- Operate for 1 year

**Customers:** DLA Distribution Warner Robins, DLA Distribution Susquehanna Pennsylvania

### DOD Benefits:

- Support improved H<sub>2</sub> storage capacity to make fuel cells more applicable to a wider range of applications
- Increased operational efficiency

**Performers:** Center for Transportation and the Environment (CTE), Alliant Techsystems Inc. (ATK), Lynntech, Inc.

### Schedule/Milestones:

- Phase I (design) award – Apr 2009
- Detail design complete – Aug 2009
- Phase II (build) – Jan 2010
- Demonstration – 2011-2012

# Lessons Learned – End User's Perspective



- Cost planning is difficult – plan a buffer for overruns
- H<sub>2</sub> Infrastructure sizing is important and requires detailed planning and understanding of needs (ex: digester gas seasonality):
  - Too large means high per unit costs, while too small results in excessive delivery charges and/or occasional shortages
  - Will need full year or more of data
  - May require planning for make-up fuel
- Indoor refueling raises eyebrows (safety)

# Lessons Learned – End User's Perspective



- Plan for future expansion in initial design
- High level evangelists can make things happen, but...
  - Must have user buy-in (not just management)
- Plan on buying and maintaining spare fuel cells. This adds cost, but may be cheaper than downtime .
- Related topics:
  - Power Purchasing Agreement (PPA) for DoD facilities takes a long time and can be complicated
  - Solar array placement has limitations (rooftop installations have load concerns)

# Business Case and Operational Data



## Cost's considered:

- Fuel cell vs. Battery costs
- Fueling vs. Charging infrastructure costs
- Maintenance costs
- Utility costs
- Floor space rqmnts
- Refueling vs. recharging time
- Equipment lifespan

## Operational Data Collected:

- Continuous and peak power
- Operational efficiency and degradation
- Overall lifecycle efficiency
- Mean time between failures and failure analysis
- Filling/dispensing operations
- Hydrogen production quality (purity)
- Balance of plant factors (kWh in/out)
- Other runtime details

# Lessons Learned – Business Case



- Cost considerations:
  - H<sub>2</sub> infrastructure makes up about 30% of the overall cost
  - Major costs: H<sub>2</sub> delivery and storage, fuel cell O&M, infrastructure, alternative (battery) cost, power
  - Less major costs: real estate costs and labor

# Lessons Learned – Everything matters



- Utilization matters
  - Fuel cells provide better payoff the more intensely forklifts are used (best at 2+ shifts/day, 365 days/year)
- Existing infrastructure matters
  - Fuel cells are not economic where current infrastructure enables quick battery changes
- Location matters
  - Fuel cells are more economic in places with costly labor, real estate and power. They are less so with higher natural gas costs

# Lessons Learned – Everything(+) Matters

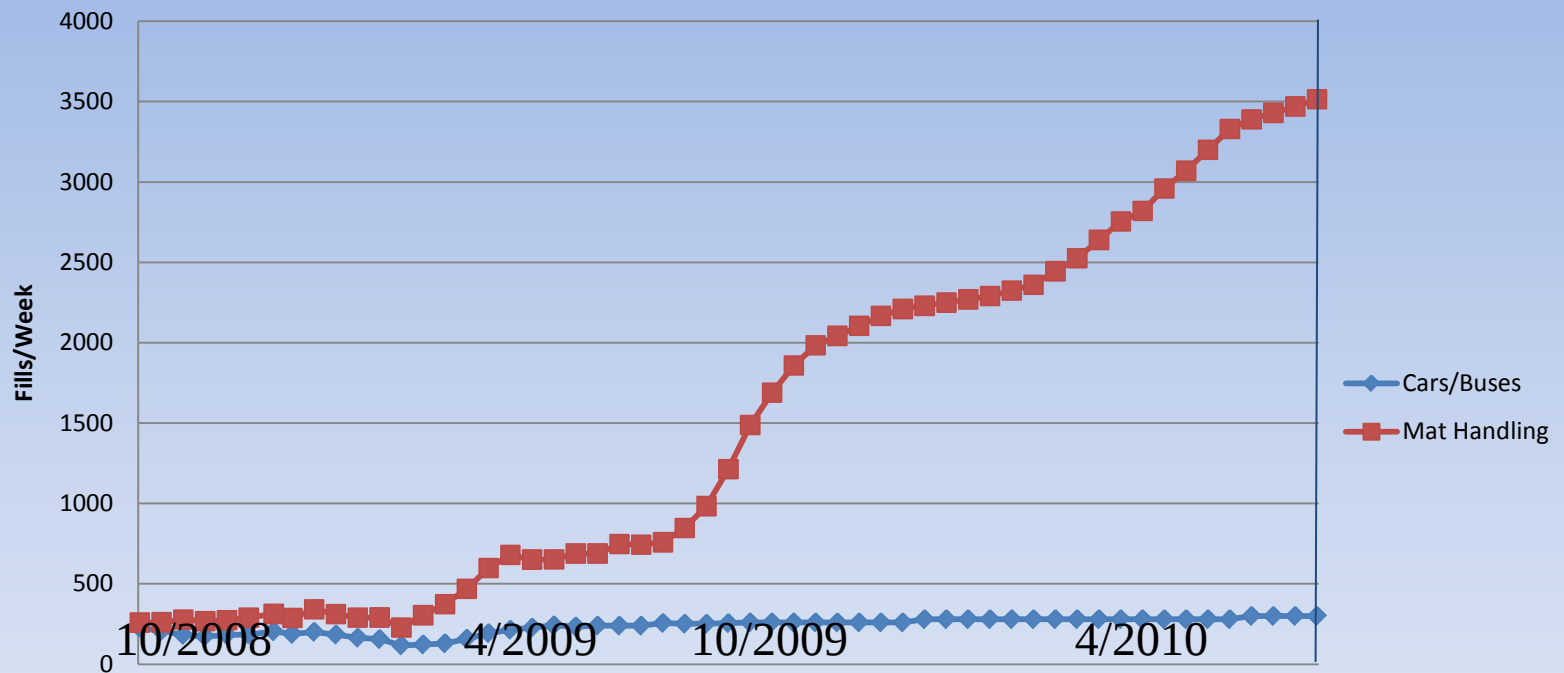


- Scale matters
  - High infrastructure and per unit O&M costs are problematic for small operations
- Delivery matters
  - Liquid H<sub>2</sub> is usually the cheapest source.
  - Onsite H<sub>2</sub> production is costly because of a lack of scale economy

# Lessons Learned – Learning by Doing



**Air Products Count by Segment**



Courtesy Air Products and Chemicals, Inc.

# Summary



- DLA pilot projects offer opportunity to learn about various implementation options for both the manufacturers and end users
- Experience relevant outside of DLA/DoD
- Cost continues to be a factor

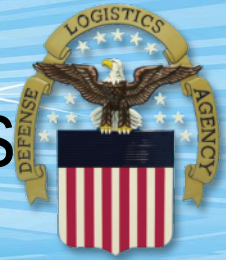
# Questions



Stu Funk  
Program Manager  
Energy and Climate Change  
LMI  
sfunk@lmi.org

Website: <https://www.dlafuelcells.org>

# Lessons Learned – TRL/MRL Improvements



- Third party FPE review, approval of system design, and installation for indoor hydrogen dispensing
- New hydrogen gas pump design and control strategy implemented for the first time
- Pump design improvements used to lower power requirements and improve efficiency and durability of the unit
- Fuel cell pack RFID identification system integration to support differentiated fill capability for certain packs

# Lessons Learned – Manufacturing



- Streamlined Fuel Cell Manufacturing Processes
  - 20-person design-build workshop.
  - Work cell layout and material flow sequencing.
  - 200% throughput improvements identified.
  - Key bottlenecks identified; additional fixtures could double production capacity on current line.

# Lessons Learned – Fuel Cell Design



- Fuel Cell Unit Design Innovations
  - Engineering redesign for new tank valve, reducing valve cost by 60%.
  - Design filter to increase cooling fan reliability.
  - New humidifier design to increase humidifier life.
  - Design and manufacturing improvements for air compressor, reducing cost by ~10% reduction.
  - Improved supplier coordination.
  - Stack improvement/cost reduction.