

Defense Logistics Agency Fuel Cell Program: Demonstrating Operational Efficiencies with Fuel Cell-Powered Lift Trucks

Fuel cell-powered forklifts are proving to be a technology that can enhance today's materials handling operations. More than 2,000 fuel cell forklifts are being installed and operated at warehouses across the United States by familiar companies such as Coca-Cola, FedEx, Wal-Mart, Nissan, BMW, Wegmans, Whole Foods, Nestlé Waters, Bridgestone-Firestone and Kimberly-Clark.¹ Similarly, the U.S. Department of Defense (DOD) Defense Logistics Agency (DLA) is exploring its ability to capitalize on the benefits of fuel cell forklifts in its warehouse operations.

To assist this fast growing market, the Department of Energy (DOE) awarded \$9.7 million in American Recovery and Reinvestment Act (ARRA) funding to support the deployment of more than 500 fuel cell forklifts at a number of commercial sites, which also includes an industry cost share of about \$11.84 million. These investments have paid off – several companies have placed follow-on orders to purchase dozens of additional fuel cell units. Fuel cells are proving to be a reliable and economical alternative to battery power in forklift applications.

DLA - a logistics combat support agency that provides supplies and services to America's global military forces - is also playing a major role in facilitating early adoption of fuel cell forklift and hydrogen fueling technologies. Through a series of pilot projects, the agency is investigating the ability of fuel cell-powered forklifts to deliver greater operational and environmental benefits compared to the battery and propane-powered forklifts currently employed at DLA warehouses.

DLA has extensive experience in moving goods. The agency's 26 distribution centers operate at a high rate of throughput, many working 24/7, using over 3,000 forklifts, stocking nearly five million items, and processing nearly 10,000 contract actions and 116,000 requisitions daily. DLA possesses one of the largest distribution warehouse storage capacities in the world, after FedEx and UPS.



Fuel cell forklift operating at the DLA
Distribution Susquehanna, PA warehouse

A fuel cell is an electro-chemical device that combines hydrogen and oxygen to produce electricity, with heat and water as its only byproducts. In structure, a fuel cell is similar to a battery, but a fuel cell may be refueled - it does not run down or require recharging. A fuel cell will produce electricity and heat as long as fuel is supplied.

¹ For a listing of fuel cell-powered forklifts are being deployed in the United States, see <http://www.fuelcells.org/info/charts/forklifts.pdf>.

The fuel cell forklift projects are allowing DLA to evaluate hydrogen and fuel cell applications, while advancing commercial readiness by providing feedback to fuel cell, component and hydrogen infrastructure manufacturers to improve the state of the technologies. The efforts of DLA and its partners to certify indoor, high pressure hydrogen fuel dispensing have resulted in revisions to the U.S. and international fire safety codes and standards that have smoothed the way for subsequent hydrogen fueling installations by private industry

DLA Distribution Susquehanna, PA, which operates round-the-clock using Class 1 sit-down battery-powered forklifts, has made an investment in a battery change-out infrastructure that shortens battery swap-outs to just four minutes and has reduced operating costs. Battery handling, charging and storage are nonetheless labor and space intensive, requiring a dedicated staff and a section of the warehouse devoted to a hoist and crane, battery recharging racks, rechargers, a battery washing station and storage for extra batteries. The recharging process is also time-intensive, requiring six to eight hours, followed by four to six hours for the batteries to cool down.

Fuel cell forklifts can potentially offer DLA greater operating efficiencies since fuel cells run several hours longer than batteries per fill up (typically an entire 8 hour shift) and can be refueled in just minutes using a hydrogen pump and dispenser. The indoor footprint of the hydrogen dispensing infrastructure is smaller, requiring significantly less valuable warehouse space than battery swap-out infrastructure. Hydrogen fuel is stored in tanks outside of the warehouse, where space is less costly.

DLA Distribution Susquehanna, PA placed 40 fuel cell forklifts into action in February 2009, using a fleet of 20 new, leased units and 20 retrofitted units. The fuel cells were provided by two companies, Nuvera and Plug Power, allowing DLA to compare the products. The fuel cell-powered forklifts are operated on all shifts and in the busiest work areas. By November 2010, the 40 units had attained more than 110,000 operating hours. In December 2010, an additional 15 new Nuvera fuel cell-powered forklifts were delivered to DLA Distribution Susquehanna, PA for a separate, one-year demonstration funded by DOE.

The fuel cell forklifts are refueled at two hydrogen dispensing pumps located inside the Eastern Distribution Center. Liquid hydrogen is delivered to the site and stored in outdoor tanks before being converted to hydrogen gas and carried, via underground pipes, to the warehouse dispensers. The hydrogen dispensing equipment has undergone significant testing during this demonstration.

Compared to incumbent power technologies, fuel cells forklifts offer:

- **Cost Savings.** Eliminates labor costs associated with changing, charging and maintaining forklift batteries. Reduces electricity demand.
- **Time Savings.** Fueling takes just a few minutes, compared to hours for batteries to be charged and cool down.
- **Smaller Footprint.** Recover valuable warehouse space through elimination of battery charging and storage infrastructure.
- **Increased Productivity.** Faster refueling and longer run times than battery-powered equipment. Constant power delivered, no loss of power over the duty cycle as when batteries discharge.
- **Reduced maintenance.** Eliminates costs spent on battery and internal combustion engine maintenance and repair, and disposal associated with lead acid batteries.
- **Environmental Benefits:** Fuel cell forklifts using hydrogen from even natural gas have considerably lower GHG emissions than those using electricity from the average U.S. grid mix* and can be operated indoors.

*<http://www.transportation.anl.gov/pdfs/TA/537.pdf>

Between February 2009 and October 2010, the 40 fuel cell forklifts were refueled more than 30,000 times and more than 17,000 kilograms of hydrogen was safely dispensed.²

In November 2009, **DLA Distribution Warner Robins, GA** became the second location to debut a pilot project, placing 20 new fuel cell forklifts into service for evaluation against propane and battery-powered forklifts already operating at base warehouses. The hydrogen production, storage and dispensing system at Warner Robins is located outdoors, with hydrogen generated on-site using a natural gas reformer. The site features a stationary hydrogen fueling dispenser, as well as a mobile refueler that can deliver hydrogen to the fuel cell forklifts operating at five different warehouse sites on the base. DLA is examining the use of mobile hydrogen refueling because of its potential to support widely dispersed warehousing operations without requiring a large investment in refueling infrastructure.



DLA Distribution Warner Robins, GA's stationary and mobile hydrogen refuelers

Two additional sites will begin fuel cell forklift pilot projects in 2011, examining low-emission, "green" hydrogen generation technologies.

DLA Distribution San Joaquin, CA is replacing 20 propane forklifts with new fuel cell-powered forklifts. Hydrogen will be generated on-site using an electrolyzer and solar power will help to make this hydrogen generation process even cleaner. DLA is working with the local power company to establish a power purchase agreement (PPA) permitting a solar array to supply green energy to the local grid, which will provide the electricity used to power the electrolyzing process.

Joint Base Lewis-McChord

(JBLM), in Pierce County, Washington, will deploy 19 new fuel cell-powered forklifts at an Army warehouse. A fuel cell bus will also to transport personnel to and from an Army/Air Force medical

Operational Data: DLA Distribution Susquehanna, PA and DLA Distribution Warner Robins, GA Forklift Fleets and Hydrogen Infrastructure

Measurements of combined fleet of 60 fuel cell forklifts from start of operations (DLA Distribution Susquehanna, PA - Feb. 2009, DLA Distribution Warner Robins, GA - Nov. 2009)

Metric	Total
Fuel cell forklift operating hours	>113,000
Number of hydrogen fuelings	>31,000
Hydrogen dispensed (kilograms)	>17,500
Average fueling time	3.3 minutes/fill
Average fueling rate	0.2 kilograms/minute
Average operating time per kilogram of hydrogen	7.5 hours
Fuel cell stack operating hours	>3,000 hours: 20% of fleet
Hydrogen infrastructure safety	No safety incidents

Source: National Renewable Energy Laboratory, U.S. Dept. of Energy and DLA

² Personal correspondence with DLA

center and across JBLM. Biomethane gas, generated as a waste by-product at the base's wastewater treatment plant and currently flared to the atmosphere, will be captured to generate hydrogen on-site for these pilot demonstration projects.



Fuel cell-powered forklift at work (Susquehanna)



Fuel cell forklift being refueled at one of Susquehanna's two indoor hydrogen dispensers

Paving the Path Forward

DLA's pilot projects have already yielded substantial benefits. Ongoing feedback from DLA is helping hydrogen, fuel cell and component manufacturers improve the readiness of their products for more widespread commercialization. The DLA, in cooperation with DOE, has helped to shape permitting standards for indoor hydrogen dispensing, which is benefitting other stakeholders. Lessons learned and communication tools devised during the projects are being shared with other sites and have helped to smooth the way for these deployments.

DLA's demonstrations have significantly increased "real world" experience and testing of hydrogen dispensing technology. The 30,000 refuelings done at DLA Susquehanna are significantly greater than is typically experienced by most hydrogen fueling sites, surpassed only by the Air Products hydrogen supply to the fuel cell lift truck operation at Central Grocers in Joliet, Illinois. Operational feedback to equipment providers is important in refining the equipment's operation and reliability.

Project data is also being made accessible to the public. Typically, information generated from operations is guarded due to proprietary or competitive considerations, but companies participating in DLA's trials have agreed to supply essential data, with results aggregated into composite data products to prevent attribution to a particular company. DLA has partnered with DOE's National Renewable Energy Laboratory (NREL) to analyze the performance and safety data collected during the trials, while an economic assessment comparing the use of fuel cell power to DLA's incumbent propane and battery powered forklifts is also underway by DLA's support contractor, LMI.

DLA Distribution Susquehanna, PA's pilot project was instrumental in shaping international codes and standards for indoor, high-pressure hydrogen dispensing. Safety codes had already been well established for hydrogen in industrial settings, and new codes added for outdoor hydrogen fueling stations will help auto manufacturers as fuel cell vehicles are commercialized. In order to safely address indoor refueling, DLA and its partners drew analogies to other gaseous fuels covered under safety codes and developed computer models to assess indoor hydrogen ventilation requirements.

These efforts led to revisions of international fire safety code and compressed gas safety code that will guide future indoor hydrogen refueling projects.³

Expanding DLA's Hydrogen and Fuel Cell RD&D

DLA is developing additional fuel cell pilot projects to capitalize on hydrogen fueling capacity at these sites, and to expand technical requirements of the projects. These include:



- **One-year trials of extended range utility vehicles.** In October 2010, DLA Distribution Warner Robins, GA deployed two fuel cell-powered utility vehicles with a 300-mile range, using compressed hydrogen fuel. DLA Distribution Susquehanna, PA deployed two extended range utility vehicles in January 2011 using solid hydrogen storage.
- **Fuel cell yard tractors.** This project is currently in the design phase and will be evaluated for operational demonstration at DLA Distribution Susquehanna, PA and DLA Distribution Warner Robins, GA in Phase II.

In summary, DLA's demonstrations are helping to advance the fuel cell and hydrogen markets. Fuel cells are a clean energy conversion technology that offers the opportunity to reduce DOD's use of energy while minimizing environmental impact. Operational and cost benefits are already accruing to commercial enterprises operating fuel cell forklifts, and this to some degree is attributable to the leadership provided by DLA as an early adopter of this promising technology.

For more information on DLA's fuel cell projects, please visit www.dlafuelcells.org. The National Renewable Energy Laboratory (NREL) reports public technical analysis results from ARRA and DLA forklift deployments in the form of composite data products, which can be viewed at http://www.nrel.gov/hydrogen/proj_fc_market_demo.html.

Learn more about fuel cells and their applications at www.fuelcells.org.

³ Leo Plonsky, Rob Hardison, Mike Canes and Tom Joseph. *A Multidisciplinary Approach to Fostering Adoption of Hydrogen Fuel Cells*. DSP Journal, Jul./Sept. 2009.

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DLA's Fuel Cell Pilot Projects

Site	Operational Phase	Forklifts	Fuel Cell Manufacturer	Hydrogen Infrastructure ¹	Hydrogen Production	Follow-on Projects ²
DLA Distribution Susquehanna, PA	<i>Feb. 2009 – Oct. 2011</i>	20 new fuel cell forklifts	Nuvera	Outdoor cryogenic hydrogen storage tank Two indoor hydrogen dispensers located inside the Eastern Distribution Center	Delivered hydrogen	Extended range fuel cell utility vehicle using solid hydrogen storage (<i>planned</i>) Fuel cell-powered yard tractors (<i>in design phase, possibility of pilot project at DLA Distribution Warner Robins, GA, may also be tested at DLA Distribution Susquehanna, PA</i>)
		Retrofitted fuel cells onto 20 existing battery-powered forklifts	Plug Power			
	<i>Dec. 2010 – Dec. 2011</i>	15 new fuel cell forklifts ³	Nuvera			
DLA Distribution Warner Robins, GA	<i>Nov. 2009 – Nov. 2011</i>	20 new fuel cell forklifts replacing 20 battery and propane-powered forklifts	Hydrogenics	Outdoor storage and dispensing using a mobile hydrogen refueler	Hydrogen reformed from natural gas	Extended range fuel cell utility vehicles using compressed gaseous hydrogen (<i>Oct. 2010 – Oct. 2011</i>) and solid hydrogen storage (<i>planned</i>) Fuel cell-powered yard tractors (<i>in design phase, possibility of construction for a one-year pilot demonstration at DLA Distribution Warner Robins, GA</i>)
Joint Base Lewis-McChord, Washington (JBLM)	<i>Planned start in 2011 (two-year demonstration)</i>	19 new fuel cell forklifts (also testing a fuel cell-powered bus)	Plug Power	Outdoor gaseous hydrogen storage with cryogenic backup Outdoor dispensing system located on nearby loading dock	Delivered hydrogen and hydrogen generated using digester gas from the installation's wastewater treatment plant (methane gas is currently flared to the atmosphere)	The Garrison Commander at JBLM has expressed strong interest in continuing this effort beyond the end of the pilot demonstration phase.
DLA Distribution San Joaquin, CA	<i>Planned start in 2011 (two-year demonstration)</i>	20 new fuel cell forklifts replacing propane forklifts	Plug Power	Outdoor gaseous hydrogen storage Outdoor dispensing system	Hydrogen generated by solar-powered electrolysis	Informal interest has been expressed by CARB (California Air Resources Board), CEC (California Energy Commission), and CaFCP (California Fuel Cell Partnership) personnel in expanding this pilot to include a dual-use public hydrogen refueling station in the future.
<u>SUMMARY</u>	► 2009 – 2013	► 114 fuel cell-powered forklifts at four sites ► 1 fuel cell-powered bus	► Three fuel cell manufacturers	► Indoor hydrogen dispensing/ outdoor hydrogen storage ► Mobile hydrogen refueling	► Delivered hydrogen ► Onsite natural gas reforming ► Hydrogen generation from waste biogas ► Solar-powered electrolysis	► Extended range fuel cell-powered utility vehicles using gaseous and solid hydrogen storage ► Additional hydrogen and fuel cell projects may be added, e.g., fuel cell-powered yard tractors

¹ Hydrogen infrastructure and delivered hydrogen from Air Products and Chemicals.

² Follow-on projects take advantage of DLA's investment in hydrogen fueling infrastructure to explore additional fuel cell technologies and to examine innovative onboard hydrogen storage technologies.

³ Project funded by the U.S. Department of Energy.