Early Markets: Fuel Cells for Material Handling Equipment

Overview

Fuel cells can be used to produce power for many end-uses in stationary, transportation, and portable power applications. By directly converting the chemical energy in fuels such as hydrogen, natural gas, or biogas to electricity, fuel cells can efficiently provide power while at the same time producing almost no harmful air pollutants.

Fuel cell systems are commercially available today for several applications. One of these emerging markets is in material handling equipment (MHE) including counterbalanced forklifts, narrow aisle lift trucks, pallet jacks, and stock pickers. MHE can use Polymer Electrolyte Membrane (PEM) fuel cell systems, which can be fueled with hydrogen, or by using methanol in Direct Methanol Fuel Cells (DMFCs).

The Case for Fuel Cells

Typically MHE is powered by gasoline, propane, or diesel-fueled engines for outdoor operations or by using lead-acid batteries for indoor applications where emissions must be controlled. The logistics of battery lift truck operation present several challenges, especially for high freight volume throughput with multiple daily shifts. Battery issues include special electrical infrastructure and maintenance requirements, including the time needed for frequent battery changes (approximately 15-20 min/shift in many facilities) and battery cool down. Also, battery-powered MHE requires infrastructure for extra batteries, battery storage, charging equipment, battery changing areas, and battery maintenance (wash stations, showers, watering equipment, etc.).

Unlike batteries, fuel cells can be rapidly refueled, boosting productivity by eliminating the time and cost associated with battery change-outs and charging. Fuel cell powered lift trucks can reduce the labor cost of refueling/recharging by up to 80% and require 75% less space as compared with battery recharging infrastructure.[1] In addition, fuel cells provide consistent power throughout shifts, while battery performance often degrades.

With their proven performance capabilities, short refueling times, and the potential for increasing productivity, fuel cells can be cost-competitive with batteries on a lifecycle basis. Additionally, fuel cells are currently eligible for a federal tax credit of up to $3,000/kW or 30% of the capital equipment expense, making them even more financially attractive.

Fuel cell lift trucks at FedEx Freight in Springfield, Missouri.

Summary of Fuel Cell Technology Cost Advantages Compared to Batteries

- Lower total cost of ownership
- 80% lower refueling / recharging labor cost
- 75% less space as compared with battery recharging infrastructure

Based on preliminary analysis of early MHE deployments, cost of ownership and operational assessment shows significant advantages of fuel cell powered lift trucks compared to battery powered units.

By investigating the total cost of ownership of fuel cell MHE, NREL found that in multiple-shift operations where a large truck fleet is used, fuel cell material handling power units and their required infrastructure have a lower total cost of ownership compared to their battery counterparts, owing to savings due to increased productivity, and decreased truck maintenance and necessary warehouse space.

Practical Use

Through the American Recovery and Reinvestment Act (ARRA) and annual appropriations, the U.S. Department of Energy's (DOE) Fuel Cell Technologies Office supported nearly 700 fuel cell powered lift trucks, along with hydrogen fueling systems, data collecion and analysis systems, as well as operator training. Data collected from all of these projects are aggregated as composite data products to provide relevant technology status results and fuel cell performance data without revealing proprietary information (See "Tracking Fuel Cell Performance" on next page). These publicly available data products provide critical information to future investors and customers (http://www.nrel.gov/ hydrogen/proj_fc_market_demo.html).

PEM fuel cell powered MHE is used at dozens of warehouses, distribution centers, and manufacturing plants. ARRA has supported early fuel cell material handling fleets operated by

Comparison of PEM Fuel Cell- and Battery-Powered MHE[3]

Green Text = Advantage	10kW Class I Forklift		3kW Class III Pallet Jack	
	Fuel-Cell Powered	Battery-Powered	Fuel-Cell Powered	Battery-Powered
Annual Cost of Ownership Per Lift (Total)	$17,800	$19,700	$11,700	$12,400
Fuel Cell / Battery System Maintenance	$2,200	$3,600	$500	$400
Facilities Space for Refueling / Recharging Infrastructure	$500	$1,900	$500	$1,900
Cost of Fuel / Electricity	$2,400	$500	$1,400	$400
Labor Cost of Refueling / Recharging	$800	$4,400	$500	$3,200
Annual Cost of Infrastructure Capital & Maintenance	$3,700	$1,400	$3,700	$1,300
Annual Cost of Fuel Cell / Battery Systems	$2,600 ($3,700 w/o tax credit)	$2,300	$1,300 ($1,800 w/o tax credit)	$1,300
Annual Cost of Lift Truck Capital & Maintenance	$5,600	$5,600	$3,900	$3,900
Operational Characteristics				
Time for Refueling / Changing Batteries	6-8 min/day	30-45 min/day	3-5 min/day	25-35 min/day
Number of Fuel Cell / Battery Systems for Multiple Shift Operations	1	2-3	1	2-3
Total Fuel Cycle Energy Use (total energy consumed/kWh delivered to the wheels)	~12,000 Btu/kWh	>14,000 Btu/kWh	~12,000 Btu/kWh	>14,000 Btu/kWh
Fuel Cycle Greenhouse Gas Emissions (g CO_2 equivalent)	800 g/kWh	1,200 g/kWh	800 g/kWh	1,200 g/kWh
Estimated Product Life	8-10 years	4-5 years	8-10 years	4-5 years
No Harmful Air Emissions at Point of Use	✔	✔	✔	✔
Quiet Operation	✔	✔	✔	✔
Wide Ambient Operating Temperature Range	✔	✔	✔	✔
Constant Power Available Over Shift	✔		✔	

The comparison of key performance and cost metrics for fuel cell and battery powered lifts are summarized in the table for Class 1 and Class III equipment. Based on NREL analysis, fuel cell MHE out-performs battery MHE in maintenance, facility space, refueling, recharging time, and product life; resulting in a lower annual cost of ownership for the equipment. Data based on preliminary analysis of early MHE deployments.

Sysco Foods, FedEx Freight, GENCO (at Wegmans, Coca-Cola, Kimberly Clark, Sysco Foods, and Whole Foods), and H-E-B Grocers.

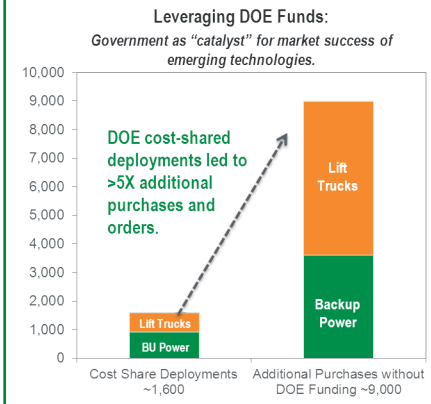
Successful DOE-funded projects have led to an industry investment of more than 5,000 fuel cell lift truck purchases or orders without any DOE funding.[2] Notable deployment examples span diverse industries, including grocery distribution centers, beverage handling facilities, and automotive manufacturing operations. Central Grocers in Illinois is operating solely on fuel cell-powered MHE with over 200 fuel cell lift trucks in one of its distribution centers. Sysco Foods is operating fleets totaling over 750 lift trucks for its operations in Texas, Pennsylvania, Massachusetts, New York, and Virginia. Additionally, Walmart has deployed more than 500 fuel cell material handling systems for grocery and food handling operations, and Wegmans has incorporated more than 130 fuel cell lift trucks into warehouse facilities. Fuel cell lift trucks are also operated in numerous automotive-related manufacturing facilities, including plants operated by Mercedes-Benz, Toyota, BMW, Nissan, and Michelin.[3] Many leading American businesses are choosing fuel cells to power their MHE because of the productivity gains, lower overall cost, and performance advantages of fuel cell lift trucks. NREL's early analysis showed a 10% lower total cost of ownership with fuel cell material handling equipment and these savings are expected to increase as the technology advances.

Fuel cell powered lift trucks at H-E-B Grocers in San Antonio, Texas.

Tracking Fuel Cell Performance

To assist in the commercialization efforts, the U.S. Department of Energy and the National Renewable Energy Laboratory analyzed and reported on hundreds of fuel cell lift trucks in operation. In about two years of operation, government supported fleets logged nearly one million operating hours, fueled from more than 187,000 kilograms of hydrogen dispensed indoors safely from more than 250,000 fueling events.

According to this data analysis, hydrogen fuel cell lift trucks can be refueled in 2.3 minutes, on average, and facilities operate the lifts for 4 – 8 hours on a single fill. For more detail on the findings of these projects, please view the final report here: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/learning_demo_final_report.pdf.



Leveraging DOE funds: DOE deployments led to >5X additional purchases by industry.

Food distribution and handling facilitites at Sysco in Houston, Texas.

For More Information

For more information, visit http://www.hydrogenandfuelcells.energy.gov.

References and Notes

1. An Evaluation of the Total Cost of Ownership of Fuel Cell Powered Material Handling Equipment, National Renewable Energy Laboratory, April 2013, http://www.nrel.gov/hydrogen/cfm/pdfs/56408.pdf
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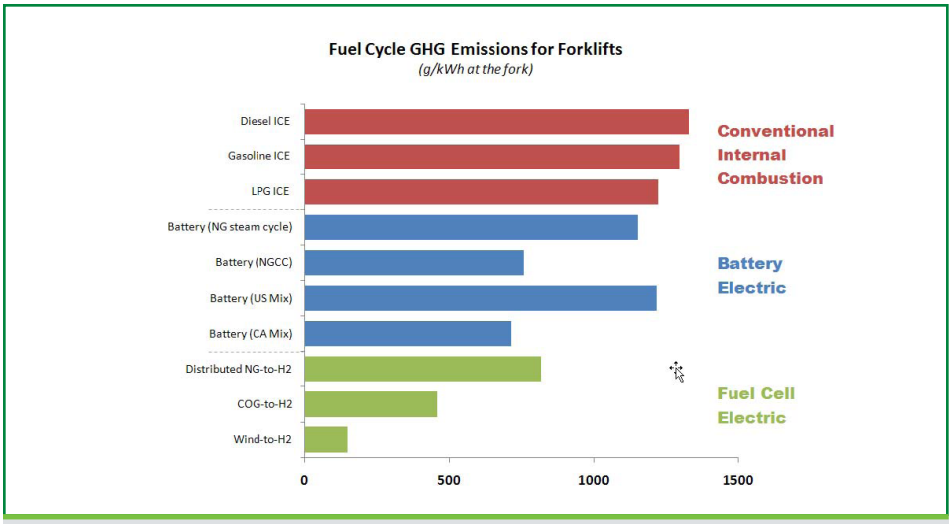

Greenhouse Gas (GHG) Emissions from fork lifts (g/Wh at the point of use). Specialty vehicles (including lift trucks) have become a key early market for fuel cells, where hydrogen and fuel cells can offer substantial reductions in emissions and significant benefits to the end-user in terms of economics and performance.[4]

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DOE/EE-0751 • February 2014
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