Commercialization of Fuel Cell Electric Material Handling Equipment

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Introduction

Hydrogen powered fuel cell electric material handling equipment and other specialty vehicles/equipment are now commercially available and competitive with conventional equipment. These specialty vehicles include forklifts, material handling equipment, airport tugs, street sweepers, and wheel loaders. They are used by a variety of industries, including manufacturing, transportation/shipping, construction, agriculture, food sales, retailers, and wholesalers.

*Fuel Cell Powered Material Handling Equipment**

The benefits and market drivers of fuel cell powered material handling equipment includes:

- Indoor and sensitive environment operation (such as food warehouses) with zero emissions;
- Lower annual cost of ownership, and nearly double the estimated product life of battery powered equipment;
- Full power operation for up to eight hours without loss of voltage before refueling;
- Fast refueling (2- 4 minutes) to allow 24/7 use with minimal downtime;
- Elimination of battery storage and charging rooms; and
- High efficiency and safety.

Market Potential

The global forklift market was valued at $35.3 billion in 2014 and is projected to expand at a compound annual growth rate of 6.9 percent to reach $55.9 billion by the end of 2021.[1]

Key market drivers of the global forklift truck market include:

- Expansion of warehouse space globally;
- Growing e-commerce business across the globe;
- Strong demand for forklift truck replacement in developed markets;
- Emphasis on reduced emissions in the working environment; and
- Purchase of low-cost forklift trucks in emerging markets.

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[1] Persistence Market Research (PMR), "Global Market Study on Forklift Trucks: Asia-Pacific to Witness Highest Growth by 2021." https://www.persistencemarketresearch.com/market-research/forklift-trucks-market.asp; October 2015.
* Image - Plug Power; http://www.plugpower.com/2017/12/plug-power-named-to-food-logistics-2017-fl100-top-software-and-technology-providers-list/

According to a Persistence Market Research (PMR) analyst, "The global material handling equipment market is growing significantly at an annual growth rate of 3% to 7%. Electric type forklift trucks are one of the prominent segments in this market. These trucks are gaining traction due to the implementation of various advanced technologies and their growing application across various industries worldwide."[2] In 2015, approximately 142,000 (roughly 66 percent) of the total 225,534 lift trucks sold in the North America were electric as opposed to engine-powered.[3]

Availability

Conventional choices for material handling equipment include diesel, propane, and battery electric powered equipment. Battery electric powered equipment has been the technology of choice for indoor use where zero emission vehicles are preferred or required for health and safety. However, challenges with battery electric material handling equipment include: long recharging time that requires vehicle isolation and downtime from fleet operation; accelerated depletion of charge in cold environments; voltage drops and reduction in power during use that results in slower operation or increased wear on motor controllers; and the need to commit facility space for recharging, storage, and handling of heavy batteries to cycle into the fleet as needed. Overall, fuel cell electric material handling equipment can resolve these issues by carrying compressed hydrogen onboard with conversion of the hydrogen to electric motive power through a high efficiency fuel cell.

A failure in material handling equipment can create significant delay to the core business that represents risk in production capability. Consequently, there is an expectation to use only tried and proven machinery. Consistent with market drivers and availability of advanced technology, over 19,000[4] fuel cell forklifts have logged in more than 121 million hours of runtime with over 5 million fills to date; users include Procter and Gamble, Walmart, Kroger, BMW, Home Depot, and Amazon.

Fuel cell electric material handling equipment is achieving an apparent high level of satisfaction. For example, at a food storage warehouse location in New Jersey, the operators calculated that annual productivity gains resulted in 590 hours per truck for a 2 shift operation, and a reduction in electric bills by 31.5 percent after switching to fuel cell powered material handling equipment. Fuel cell electric material handling equipment is replacing battery-powered forklifts. There is also the potential for fuel cells to power vehicles and equipment in ports, construction, agriculture, and mining operations.

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[2] Persistence Market Research (PMR), "Global Forklift Truck Market to Reach US $55.9 Billon by the End of 2021;" http://www.mmh.com/article/global_forklift_market_to_grow_by_nearly_7_through_2021; September. 30, 2015.
[3] Industry Truck Association, "North American Forklifts Have Record 2015 Sales; Nearly 2/3 Were Electric." https://www.inddist.com/news/2016/02/north-american-forklifts-have-record-2015-sales-nearly-2-3-were-electric; February 24, 2016.
[4] Plug Power, "FAQ from potential GenDrive customers," http://www.plugpower.com/2017/12/faq-from-potential-gendrive-customers/; December 12, 2017.

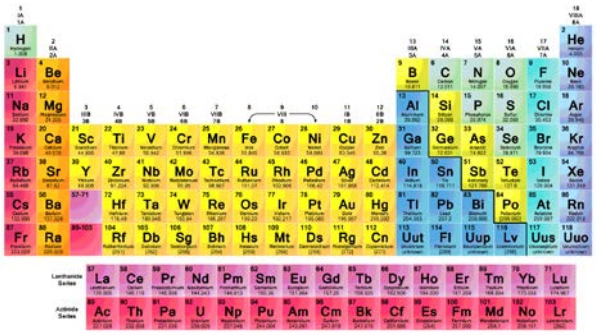
Hydrogen Production

Fuel cell electric material handling equipment will not require facility space for battery storage and electric battery recharging; however, it will require hydrogen production and/or storage for the fueling. Consequently, hydrogen fueling must be considered and included in all cost and cash flow comparative analyses. Hydrogen dispensing infrastructure is relatively compact compared to electric battery charging racks and has been commercially available for years to businesses that require hydrogen for industrial processes, food production, metals manufacturing, industrial cooling, electric generation, and in the petrochemical industry to reformulate fuels.

Hydrogen (element number one) is abundant in many natural compounds and when present as a gaseous element is lighter than air. If released, hydrogen will rise and dissipate rapidly without toxic effects. Hydrogen is best characterized as an energy carrier, similar to electricity, which can produce power without harmful air emissions and can also be stored like conventional fuels, such as propane and natural gas.

Hydrogen is typically separated from other elements to form pure hydrogen (H_2) and can be produced using a wide variety of resources found in the U.S. including renewable and intermittent energy resources. Hydrogen production methods include electrolysis of water, steam reforming of natural gas, coal gasification, thermochemical production, and biological gasification. Hydrogen can also be stored and transported using a variety of transportation, storage, and dispensing methods, including liquid hydrogen delivery, gaseous hydrogen delivery, and onsite production of hydrogen by electrolysis or natural gas reformation.

Figure 1 - Periodic Table of Elements



The option of using electrolysis to produce hydrogen can be tied with the production of electricity from renewable and intermittent energy resources, such as solar photovoltaics (PV), wind, or biomass. For example, renewable electricity produced at off peak usage times could be used to produce and store hydrogen for later use by fuel cell powered equipment and fuel cell electric vehicles (FCEVs) to meet zero emission requirements. Use of steam reformation of natural gas to produce hydrogen onsite can provide low cost hydrogen by removing the carbon (C) from natural gas methane (CH4) and the oxygen (O) from water (H_2O). Natural gas is widely available through the local distribution company utilities throughout the Northeast region and is relatively inexpensive. Consequently, natural gas shows potential to serve as a transitional fuel for the future hydrogen economy. Additionally, methane from biogas can be sourced from landfills or anaerobic digestion, allowing the hydrogen produced through steam reformation to be renewable.

Figure 2 – SimpleFuel (on-site electrolysis)

Figure 3 - Plug Power (hydrogen delivery and Storage)

Figure 4 - Proton OnSite (on-site electrolysis)

Figure 5 - Nuvera (on-site natural gas reformation)

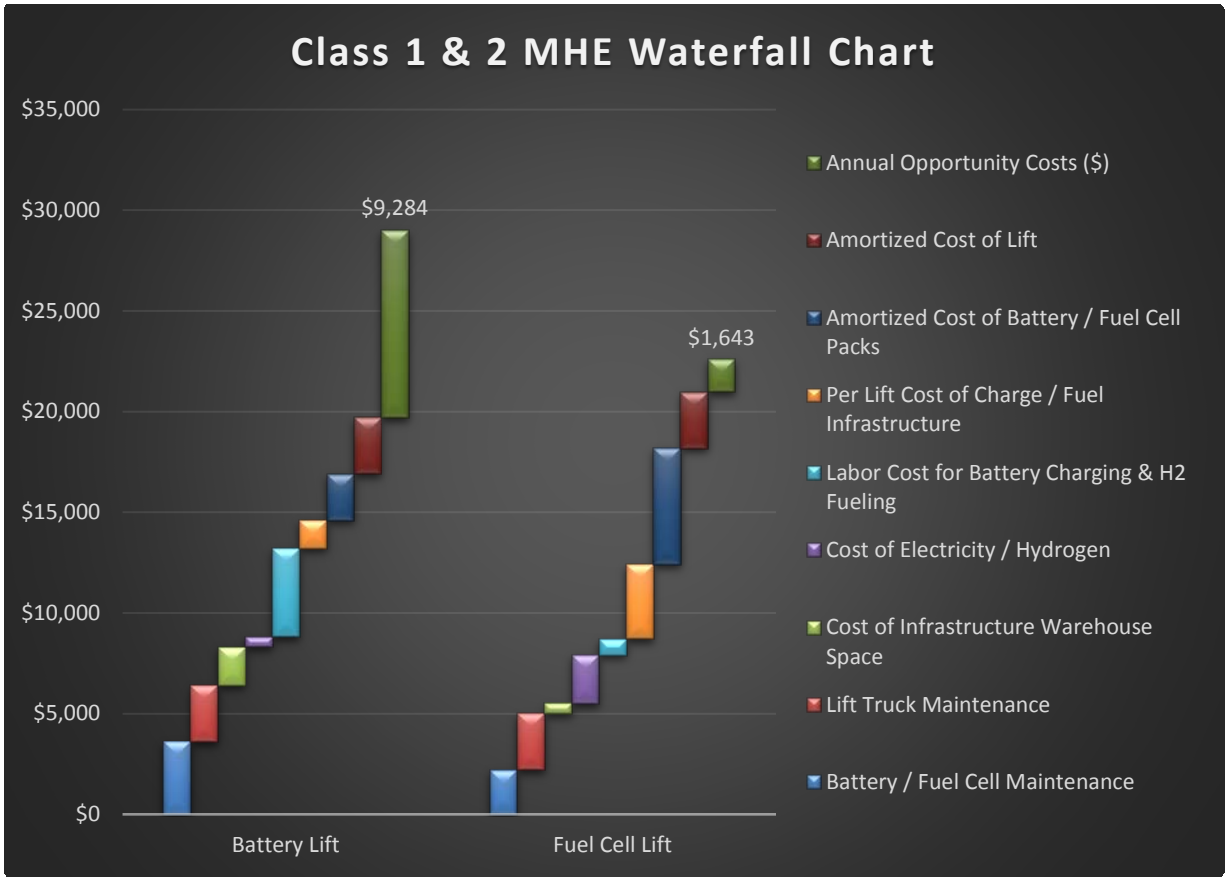
Hydrogen production and refueling technologies are often integrated with fleets of fuel cell electric material handling equipment. For example, Plug Power has developed the Gendrive system for hydrogen storage and dispensing with more than 19,000 units in the field that guarantee a minimum of 97 percent uptime at each location.

Cost

The economic attributes of fuel cell electric material handling equipment are of high value with cost being an important market driver for technology selection. The cost analysis below includes an example of direct capital expenses and indirect/operational expenses to determine the economic viability of using fuel cell powered equipment. This analysis includes a cost comparison of battery electric versus fuel cell electric material handling equipment with the following cost inputs:

- Battery / fuel cell maintenance;
- Lift truck maintenance;
- Infrastructure warehouse space for battery charging or hydrogen fueling;
- Purchase of electricity or hydrogen;
- Labor for battery charging or hydrogen fueling;
- Battery charging or hydrogen fuel infrastructure;
- Amortized cost of battery or fuel cell packs; and
- Amortized cost of lift.

Based on the comparison below, the annual cost for Class 1 and 2 fuel cell powered material handling equipment is approximately $22,600 per year, about $6,400 per year less than battery electric material handling equipment's annual costs of approximately $29,000 per year.[5] [6]



	Class 1 & 2 MHE	
	Battery Lift	FC Lift
Battery / Fuel Cell Maintenance	$3,600	$2,200
Lift Truck Maintenance	$2,800	$2,800
Cost of Infrastructure Warehouse Space	$1,900	$500
Cost of Electricity / Hydrogen	$500	$2,400
Labor Cost for Battery Charging & H2 Fueling	$4,400	$800
Per Lift Cost of Charge / Fuel Infrastructure	$1,400	$3,700
Amortized Cost of Battery / Fuel Cell Packs	$2,300	$5,775
Amortized Cost of Lift	$2,800	$2,800
Annual Opportunity Costs ($)	$9,284	$1,643
Sub-Total	*$28,984*	*$22,618*

Conclusion

[5] National Renewable Energy Laboratory (NREL); "Forklift and Backup Power Data Collection and Analysis;" https://hydrogendoedev.nrel.gov/pdfs/review13/tv021_kurtz_2013_o.pdf; May 16, 2013.

[6] This excludes the investment tax credit of 30 percent for qualified fuel cell property as identified in the Emergency Economic Stabilization Act of 2008.

All things being equal, the market for zero-emission material handling equipment favors hydrogen powered fuel cell electric technologies. Fuel cell electric material handling equipment is commercially available and can be cost competitive with consideration of all pertinent costs. Because fuel cell electric material handling equipment will require the selection of hydrogen supply equipment, the competiveness of fuel cell technology generally increases as fleet size increases. In addition, the development of hydrogen fueling to support fuel cell material handling equipment could also be coordinated with other hydrogen uses.